ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 1

EO M431.01 – EXPLAIN FEATURES OF WING DESIGN

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Obtain a model of a light fixed-wing aircraft with wing struts, fixed gear and control surface detail.

Prepare slides of the figures located at Attachment A.

Obtain a model of a wing.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize features of wing design.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain features of wing design.

IMPORTANCE

It is important for cadets to be able to explain features of wing design as it directly relates to the production of lift by the wing. Being able to explain features of wing design provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

> Use the model aircraft with articulated control surfaces and flaps throughout this lesson to illustrate features of wing design as they are discussed.

Teaching Point 1	**Explain airfoils.**
Time: 10 min	Method: Interactive Lecture

AIRFOILS

Chord. An imaginary straight line joining the leading and trailing edges of the wing. The mean aerodynamic chord (MAC) is the average chord of the wing.

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

> Show the slide of Figure A-1 to the cadets.

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

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

Conventional Airfoils

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

> Show the slide of Figure A-2 to the cadets and describe the different airfoil shapes.

Laminar Flow Airfoils

> Show the slide of Figure A-3 to the cadets and show the differences between conventional and laminar flow airfoil shapes.

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

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

Planform

> Show the slide of Figure A-4 to the cadets.

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

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

Aspect ratio. The relationship between the length of the wing and its width (chord). It is calculated by dividing the span by the average chord.

A wing with a high aspect ratio generates more lift with less induced drag than a wing with the same wing area and a low aspect ratio. High aspect ratio wings are commonly found on gliders.

Angle of Incidence

> Show the slide of Figure A-5 to the cadets.

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

The angle of incidence affects the following items:

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

Wash-Out and Wash-In

To reduce the tendency of the wing to stall suddenly, the wing can be designed so that the angle of incidence at the wing tip is different than the angle of incidence at the wing root.

Show the slide of Figure A-6 to the cadets.

The twist in the wing causes the tip and root to stall at slightly different angles of attack and improves the stall characteristics. If the wing root stalls before the wing tip, the ailerons, located closer to the wing tip, can still be effective during the early part of the stall.

Decreasing the angle of incidence at the wing tip is called wash-out and increasing the angle is called wash-in.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What happens to the transition point as airspeed and angle of attack increase?

Q2. What is the aspect ratio of a wing?

Q3. What is it called when the angle of incidence at the wing tip is decreased?

ANTICIPATED ANSWERS:

A1. The transition point moves forward.

A2. The relationship between the length of the wing and its width (chord). It is computed by dividing the span by the average chord.

A3. Wash-out.

Teaching Point 2	**Explain high-lift devices.**
Time: 10 min	Method: Interactive Lecture

HIGH-LIFT DEVICES

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

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

Wing Tip Design

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

- installing wing tip fuel tanks,
- using wing tip plates or winglets, and
- drooping the wing tips.

Show Figures A-7 and A-8 to the cadets.

Wing Fences

Show the slide of Figure A-9 to the cadets. Wing fences can also be seen in Figure A-8.

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

Slats

Show the slide of Figure A-10 to the cadets.

Auxiliary airfoils that automatically move out in front of the leading edge at high angles of attack are known as slats. The resulting opening changes the airflow over the leading edge, smoothing out eddies that form on the top of the wing.

Slots

Show the slide of Figure A-11 to the cadets. Slots can also be seen in Figure A-10.

Slots affect the airflow in the same way as slats, except that they are passageways built into the wing. Slots can either be full- or partial-span.

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

Flaps

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

Show the slide of Figure A-12 to the cadets.

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

Show the slide of Figure A-13 to the cadets.

Generally, the amount of drag produced by flaps reduces acceleration to the point where flaps should not be deployed during takeoff (as is the case with plain and split flaps). Slotted, Zap, and Fowler flaps produce more lift than drag at small amounts of deflection (5–15 degrees) and are usually recommended for takeoff.

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. How can induced drag be reduced by wing tip design?

Q2. What is the main difference between slats and slots?

Q3. What do flaps increase?

ANTICIPATED ANSWERS:

A1. Induced drag can be reduced by:

- installing wing tip fuel tanks,
- using wing tip plates or winglets, and
- drooping the wing tips.

A2. Slats are moving devices. Slots are built into the wing and do not move.

A3. Flaps increase lift and drag. They may also increase the effective wing area.

Teaching Point 3	**Explain spoilers and speed brakes.**
Time: 5 min	Method: Interactive Lecture

Show the slide of Figure A-14 to the cadets.

SPOILERS

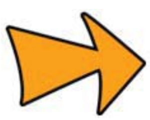
Spoilers are devices on a wing that are used to decrease the lift and increase the drag being produced. They work by being extended up from the top surface of the wing and disrupting the airflow. Spoilers are found on almost all types of gliders and are used to increase the rate of descent during the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

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

SPEED BRAKES

Speed (dive) brakes are devices that are extended into the airflow, creating drag, with minimal effect on the lift being produced. Speed brakes allow aircraft to slow down without reducing thrust, and to control approach angles.

Speed brakes may be plates that extend out of a wing or hinged doors that open out from the fuselage.



Most gliders have speed brakes that extend out of the bottom of the wing.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. Where are spoilers located?

Q2. What control surface can spoilers supplement or replace?

Q3. What do speed brakes create?

ANTICIPATED ANSWERS:

A1. On the top surface of a wing.

A2. Ailerons.

A3. Drag.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is the chord?

Q2. How can adding devices negatively affect a wing?

Q3. What do spoilers increase during the landing approach of most gliders?

ANTICIPATED ANSWERS:

A1. An imaginary straight line joining the leading and trailing edges of the wing.

A2. They create increased weight and mechanical complexity.

A3. The rate of descent.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CRR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Understanding wing design, the features that improve the efficiency of the wing and devices that produce drag to control the approach angle provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

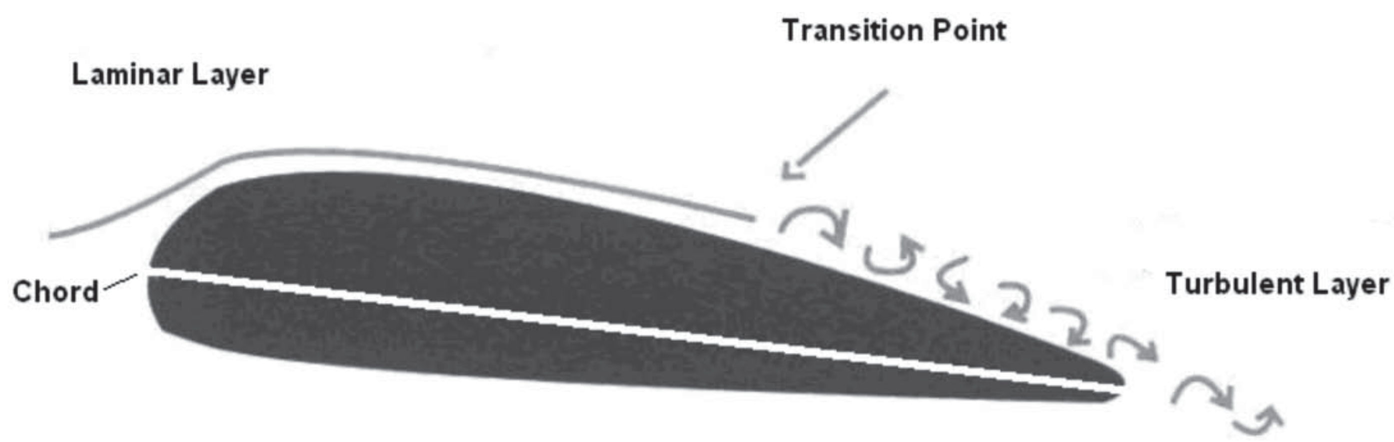
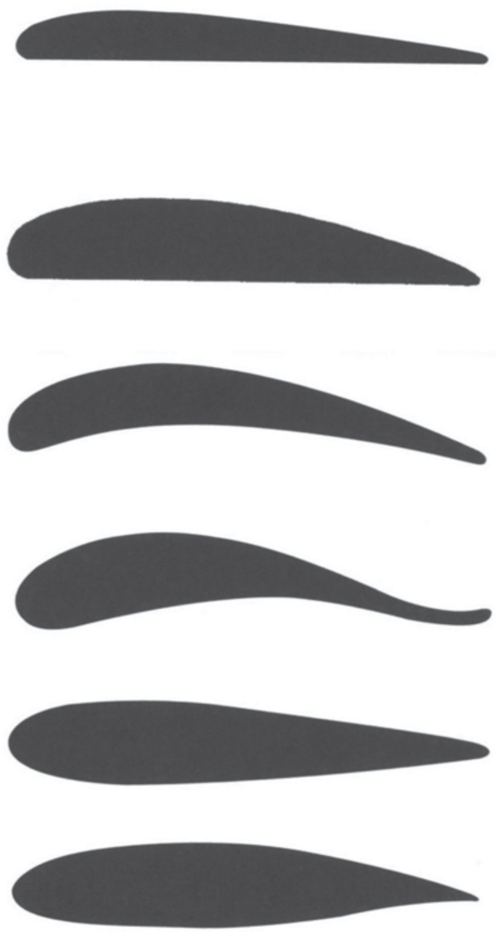


Figure A-1 Laminar and Turbulent Layers

Note. From *From the Ground Up: Millennium Edition* (p. 25), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.



Characteristics	Uses
• Low camber • Low drag • High speed • Thin wing section	• Race planes • Fighters • Interceptors
• Deep camber • High lift • Low speed • Thick wing section	• Transports • Freighters • Bombers
• Deep camber • High lift • Low speed • Thin wing section	• Transports • Freighters • Bombers
• Low lift • High drag • Reflex trailing edge wing section	• Very little movement of centre of pressure • Good stability
• Symmetrical wing section (cambered top and bottom)	• Very little movement of centre of pressure • Good stability
• GA(W)-1 airfoil • Thicker for better structure and lower weight • Good stall characteristics	• Camber is maintained farther rearward which increases lifting capability over more of the airfoil and decreases drag

Figure A-2 Airfoil Sections

Note. From *From the Ground Up: Millennium Edition* (p. 26), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

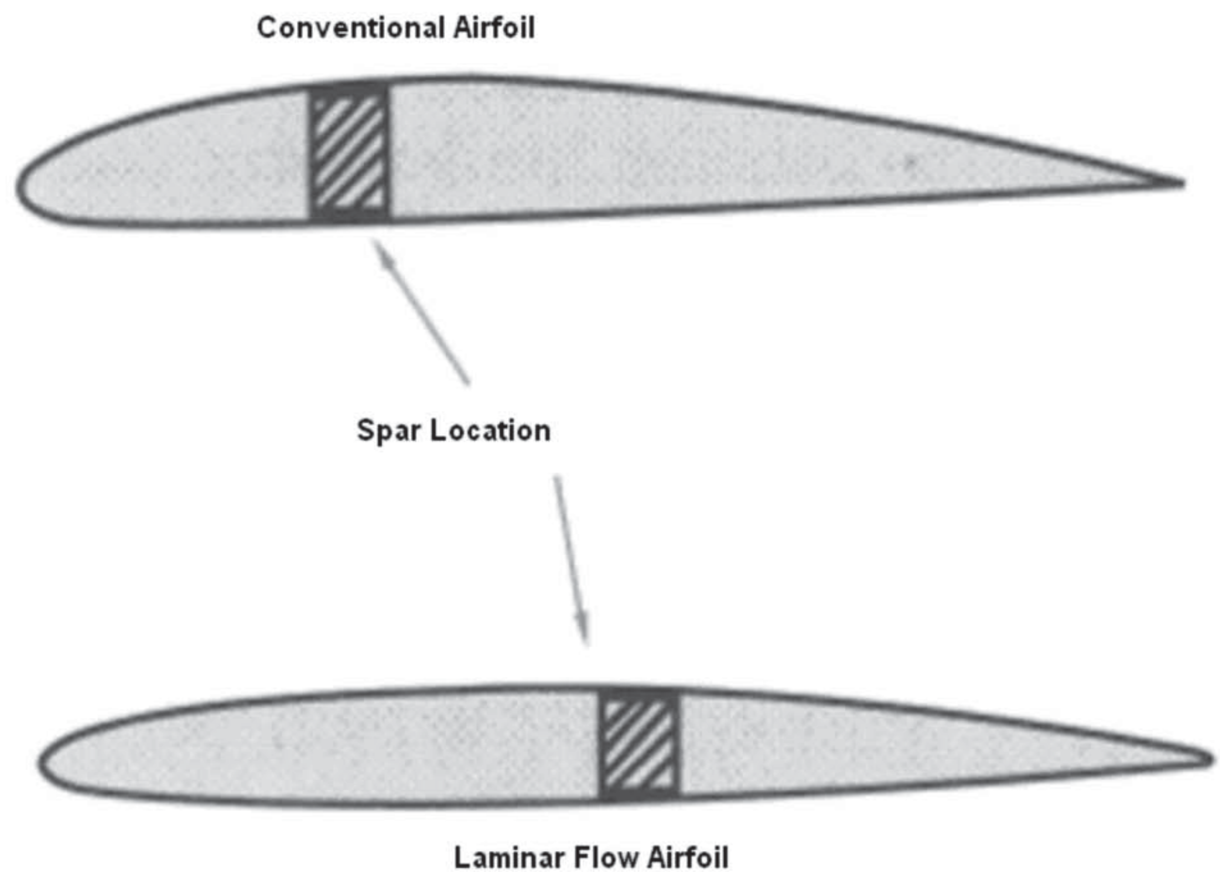


Figure A-3 Conventional and Laminar Flow Airfoils

Note. From *From the Ground Up: Millennium Edition* (p. 27), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

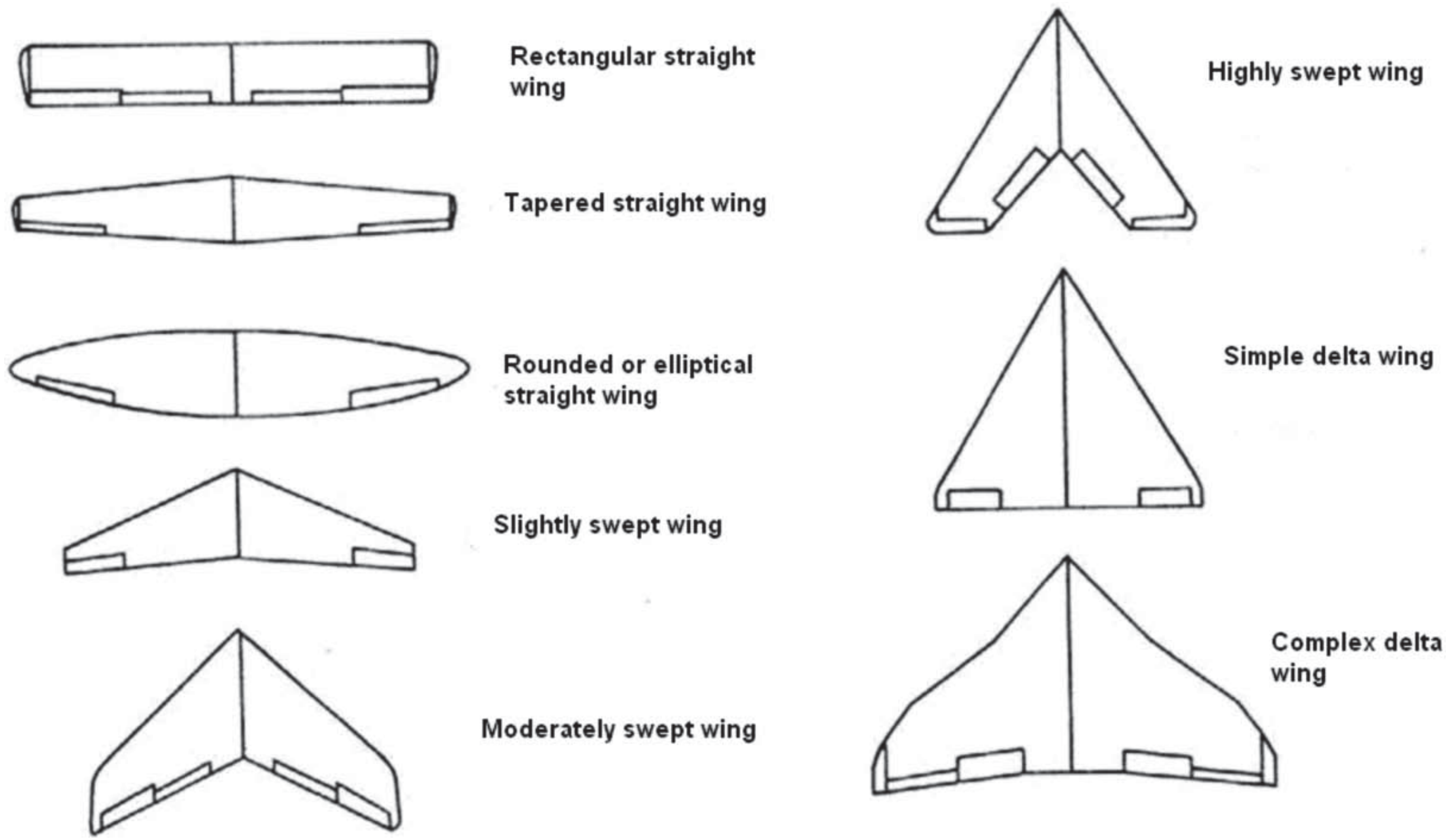


Figure A-4 Examples of Wing Planforms

Note. From "SP-367 Introduction to the Aerodynamics of Flight", *NASA*. Retrieved October 22, 2008, from http://history.nasa.gov/SP-367/f13b.htm

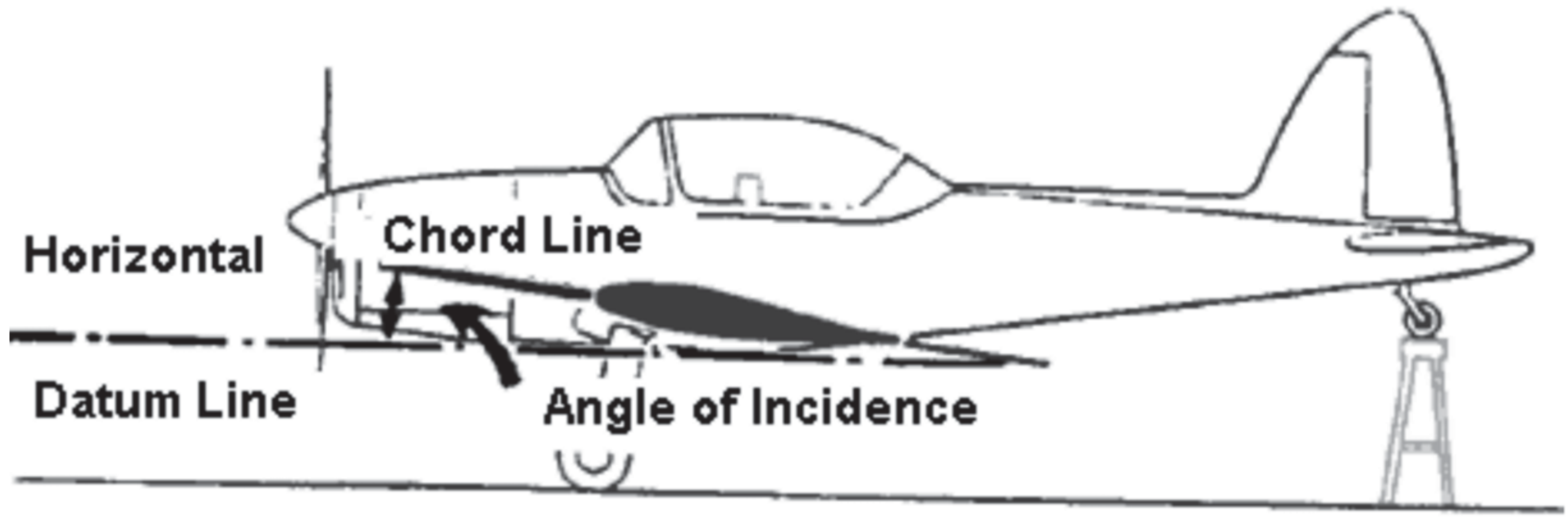


Figure A-5 Angle of Incidence

Note. From *From the Ground Up: Millennium Edition* (p. 27), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

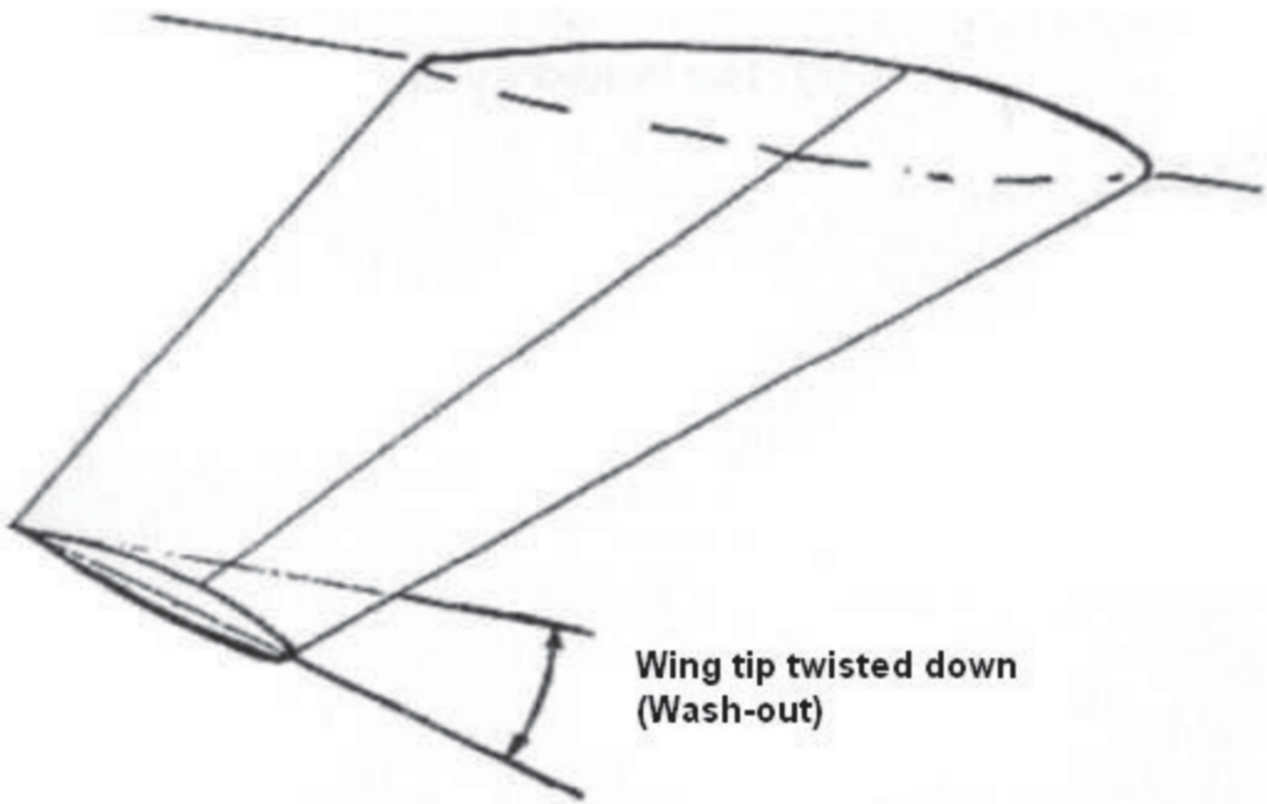


Figure A-6 Wash-Out

Note. From "Wing Twist and Dihedral", 2001, *Aerospaceweb.org*. Retrieved October 22, 2008, from http://www.aerospaceweb.org/question/dynamics/q0055.shtml

Figure A-7 Wing Tip Tanks and Winglets

Note. From "Canada's Air Force, Image Gallery, Details", 2006, *Department of National Defence*, Copyright 2006 by Department of National Defence. Retrieved October 22, 2008, from http://www.airforceimagery.forces.gc.ca/netpub/server.np?find&catalog=casimages&template=detail2_e.np&field=itemid&op=matches&value=4461&site=casimages

Figure A-8 Drooping the Wing Tips

Note. From "Cessna 170", 2008, *Barnstormers.com*. Retrieved October 22, 2008, from http://www.barnstormers.com/listing_images.php?id=266438&ZOOM=%2Fclassified_files%2F266438-DSC04234.jpg

Figure A-9 Wing Fences

Note. From "STOL Kit", *F. and H. (Aircraft)*. Retrieved October 22, 2008, from http://www.fandh-aircraft.co.uk/stol_kit.htm

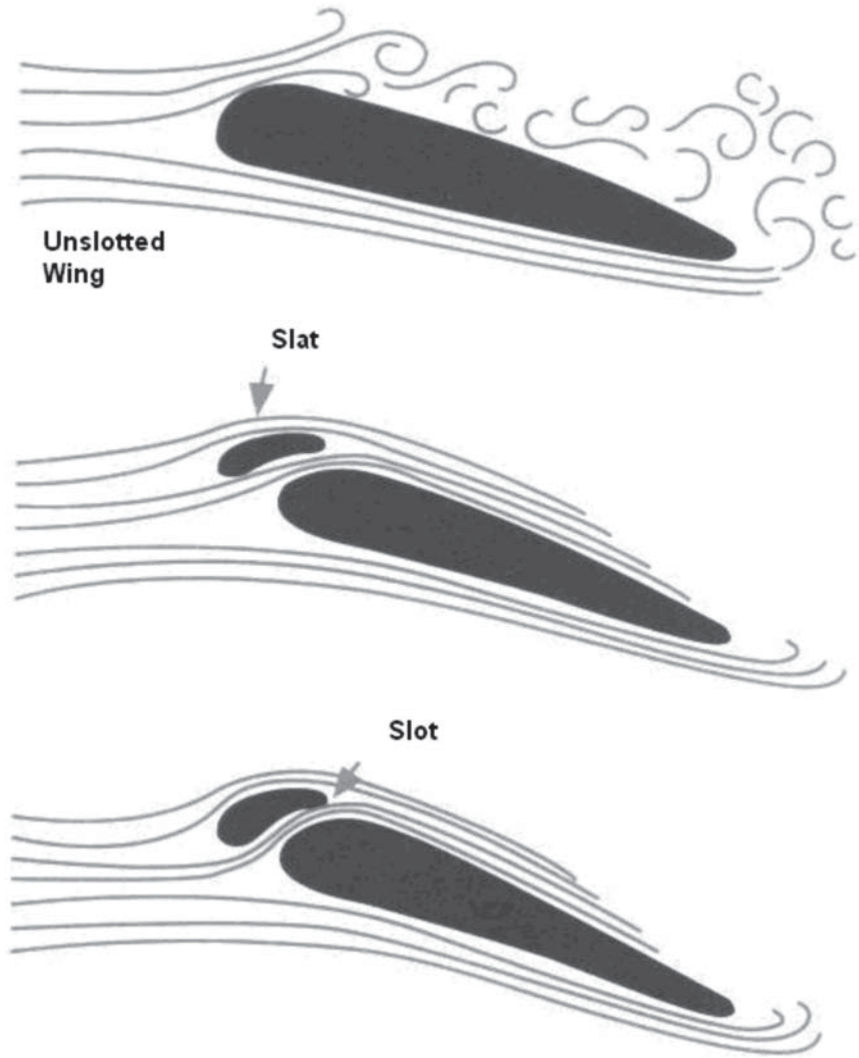


Figure A-10 Slotted Wings

Note. From *From the Ground Up: Millennium Edition* (p. 28), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Figure A-11 Leading Edge Slot

Note. From "Stinson 108", 2005, *Wikipedia*. Retrieved October 22, 2008, from http://en.wikipedia.org/wiki/Image:Stinson108-3photo03.jpg

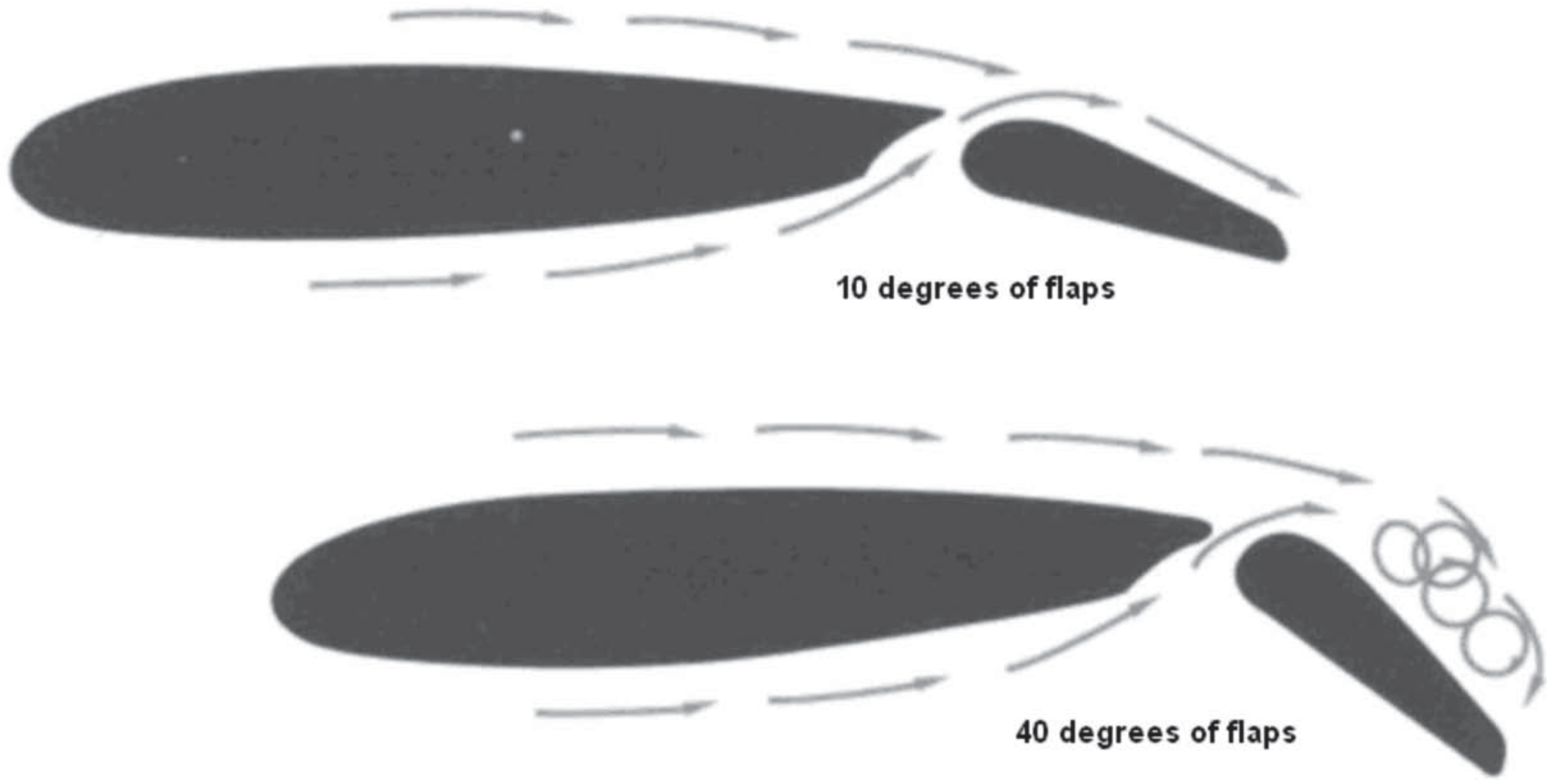


Figure A-12 Flap Settings

Note. From *From the Ground Up: Millennium Edition* (p. 29), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

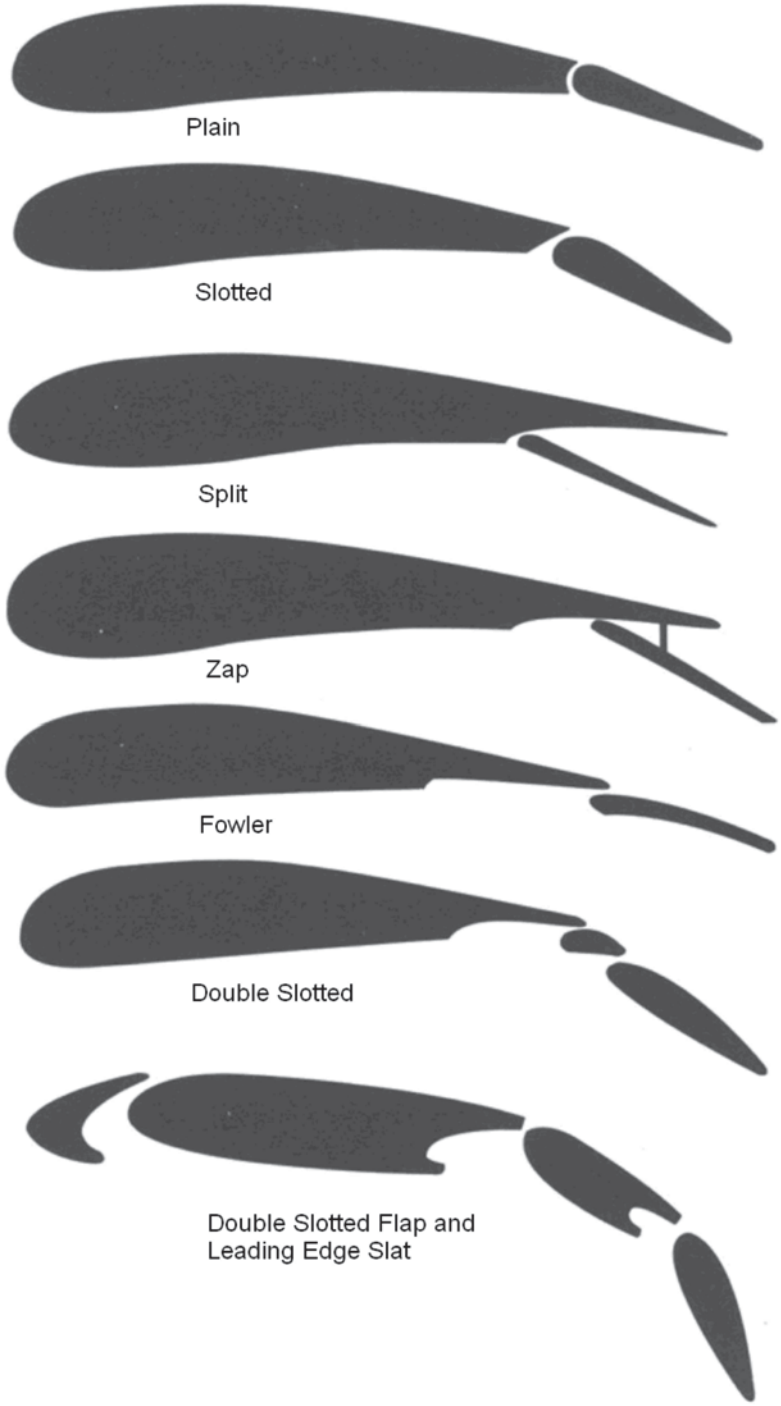


Figure A-13 Flaps

Note. From *From the Ground Up: Millennium Edition* (p. 29), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

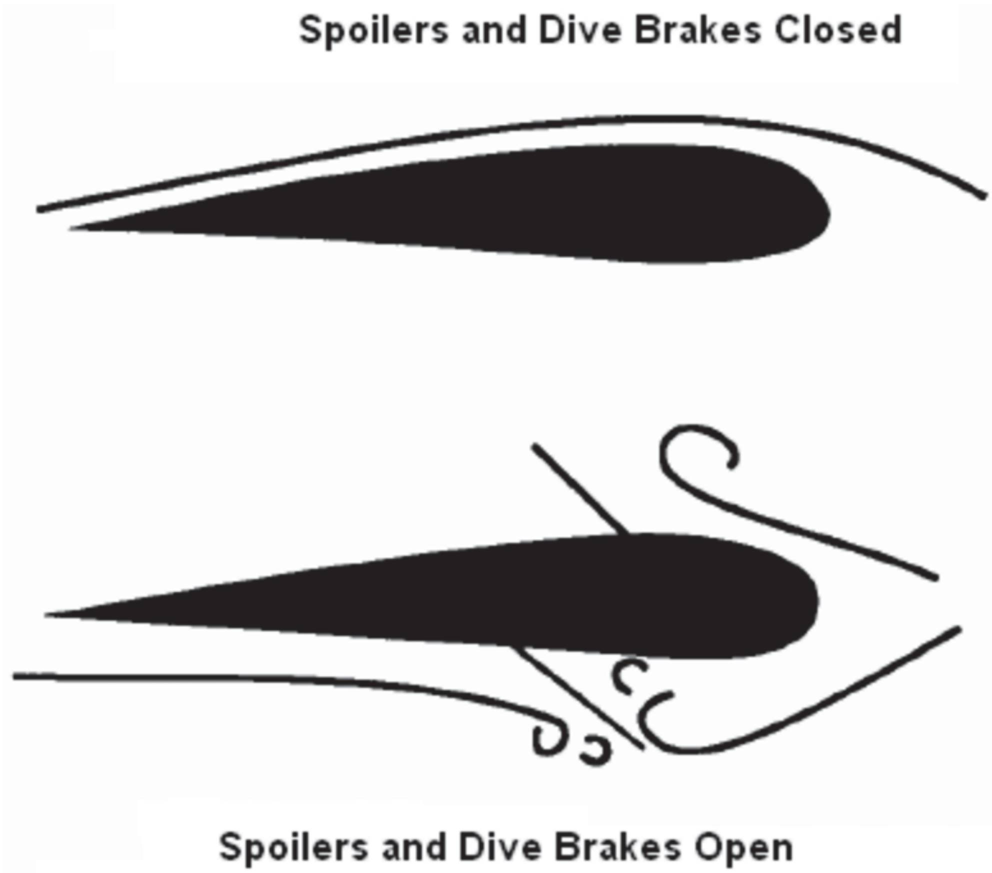


Figure A-14 Spoilers and Dive Brakes

Note. From *Air Cadet Gliding Program Manual* (p. 6-3-2), 2008, Ottawa, ON: Department of National Defence.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 2

EO M431.02 – DESCRIBE FLIGHT INSTRUMENTS

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy Attachment A for each cadet.

Prepare slides of the figures located at Attachment A.

Obtain a gyroscope for use in TP2.

Construct a working model of each of the pitot static instruments IAW Attachment C.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize and summarize flight instruments.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to describe flight instruments.

IMPORTANCE

It is important for cadets to be able to describe flight instruments as they are the basic instruments used during flight. Being able to describe flight instruments provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1	**Review the pitot static system and pitot static instruments.**
Time: 25 min	Method: Interactive Lecture

PITOT STATIC SYSTEM

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

- pitot pressure, and
- static pressure.

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

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

Show the slide of Figure A-1 to the cadets.

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

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

AIRSPEED INDICATOR (ASI)

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

ASI Markings

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

Show the slide of Figure A-2 to the cadets.

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

Yellow. A yellow arc starts at the maximum structural cruise (V_{NO}) and extends to the V_{NE}. This area is typically known as the caution range.

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

White. The range in which fully extended flaps may be used. It starts at the power-off stalling speed with flaps and gear extended (V_{SO}) and extends to the maximum flaps extended speed (V_{FE}).

ASI Errors

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

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

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

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

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

Airspeed Definitions

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

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

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

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

ALTIMETER

The altimeter is connected only to the static pressure port(s) and measures the pressure of the outside air. A sealed aneroid capsule inside the instrument case expands or contracts due to changes in the static pressure. The expansion or contraction is mechanically linked to the indicator's needles and causes them to rotate around the dial to show the altitude.

Show the slide of Figure A-3 to the cadets.

Altimeter Errors

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

"From high to low—look out below".

When an aircraft flies into an area with a relatively lower pressure, if the altimeter setting is not corrected, the altimeter will read higher than the actual altitude. For example, the altimeter may be indicating 4 000 feet, while the actual altitude may be

3 000 feet. This could cause a conflict with other aircraft, or even worse, cause the aircraft to come into contact with the ground.

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

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

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

Altitude Definitions

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

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

Density altitude. The pressure altitude corrected for temperature.

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

VERTICAL SPEED INDICATOR (VSI)

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

Show the slide of Figure A-4 to the cadets.

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

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to have the cadets practice reading pitot static instruments.

RESOURCES

- One working model of each of the pitot static instruments, including:
  - ASI,
  - altimeter, and
  - VSI; and
- Questions located at Attachment B.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into two groups.
2. Set one model at a time (in no particular order) and allow each group five seconds to read the instrument.
3. Have one group read the instrument to the class. The group gets one point for a correct answer.
4. If a group cannot correctly read the instrument then the other group can steal the point.
5. Repeat Steps 2–4 for the remaining time.
6. Declare the group with the most points the winner.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 2	**Describe the gyroscope and gyroscopic instruments.**
Time: 15 min	Method: Interactive Lecture

THE GYROSCOPE

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

Show the slide of Figure A-5 to the cadets.

Gyroscopic Inertia

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

Precession

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

Demonstrate gyroscopic inertia and precession to the cadets using a gyroscope.

Power Sources

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

Engine driven vacuum system. A vacuum pump powered by the engine. It does not work if the engine is not running (eg, prior to startup, following an engine failure). A variation of this system is an engine driven air pump that uses positive air pressure to spin the rotor.

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

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

Care of Gyroscopic Instruments

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

HEADING INDICATOR (HI)

Show the slide of Figure A-6 to the cadets.

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

The cadets will learn about the magnetic compass in more detail in EO M437.02 (Describe the Magnetic Compass).

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

Friction in the gyroscope causes a small amount of precession and will cause the reading to drift approximately three degrees over a period of 15 minutes. It is also subject to apparent precession. The rotation of the Earth gives the gyroscope an apparent motion relative to the Earth. This error varies with latitude. Apparent precession is zero at the equator and 15 degrees per hour at the poles.

Precession errors are easily corrected by resetting the HI to the current heading (by referencing the magnetic compass during straight and level flight) every 15 minutes.

ATTITUDE INDICATOR (AI)

Show the slide of Figure A-7 to the cadets.

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

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

TURN AND SLIP INDICATOR

Show the slide of Figure A-8 to the cadets.

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

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

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

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

TURN CO-ORDINATOR

Show the slide of Figure A-9 to the cadets.

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is gyroscopic inertia?

Q2. What errors affect the HI?

Q3. Which gyroscopic instrument can display the rate of roll as well as the rate of turn?

ANTICIPATED ANSWERS:

A1. Gyroscopic inertia is the tendency of a rotating object to remain in its plane of rotation.

A2. Precession and apparent precession.

A3. The turn co-ordinator.

Teaching Point 3	**Describe the angle of attack (AOA) indicator.**
Time: 5 min	Method: Interactive Lecture

ANGLE OF ATTACK (AOA) INDICATOR

Show the slide of Figure A-10 to the cadets.

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

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What does the AOA indicator display?

ANTICIPATED ANSWERS:

A1. The AOA indicator displays the relationship between the chord line of the wing and the relative airflow.

Teaching Point 4 **Describe the Mach indicator.**

Time: 5 min Method: Interactive Lecture

MACH INDICATOR

> Show the slide of Figure A-11 to the cadets.

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

> Distribute the handouts of flight instruments located at Attachment A to each cadet.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS:

Q1. How is the Mach number calculated?

ANTICIPATED ANSWERS:

A1. The Mach number is calculated by dividing the airspeed by the speed of sound.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is density altitude?

Q2. How long does it take to complete a standard rate 360-degree turn?

Q3. How does the Mach indicator work?

ANTICIPATED ANSWERS:

A1. The pressure altitude corrected for temperature.

A2. Two minutes.

A3. The Mach indicator works by measuring and correlating static and dynamic pressures.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO will be assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Future aviation training and instructional duties require knowledge of pitot static instruments, gyroscopes and gyroscopic instruments.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

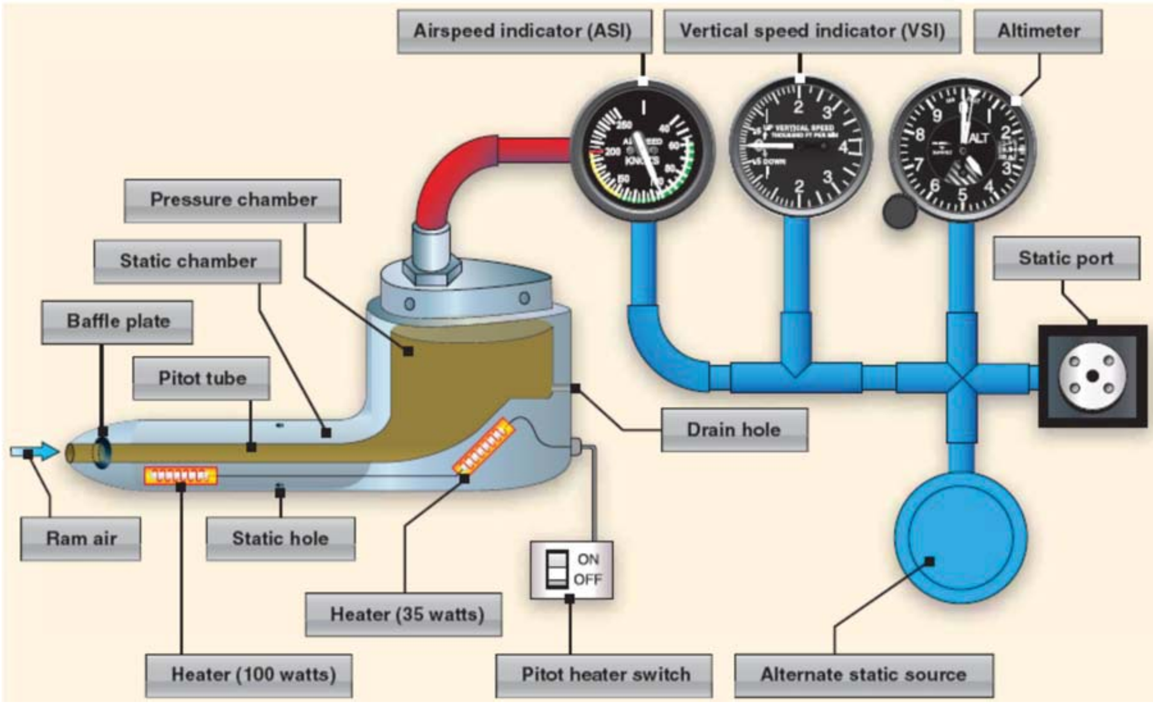


Figure A-1 Pitot Static System

Note. From "Pilot's Handbook of Aeronautical Knowledge", *Federal Aviation Administration*. Retrieved November 19, 2008, from http://www.faa.gov/library/manuals/aviation/media/FAA-H-8083-25A.pdf

Figure A-2 Airspeed Indicator

Note. From "Flight Instruments", *North American Powered Parachute Federation*. Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

Figure A-3 Altimeter

Note. From "Flight Instruments", *North American Powered Parachute Federation*. Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

Figure A-4 Vertical Speed Indicator

Note. From "Flight Instruments", *North American Powered Parachute Federation*. Retrieved October 30, 2007, from http://www.nappf.com/nappf_flight_instruments.htm

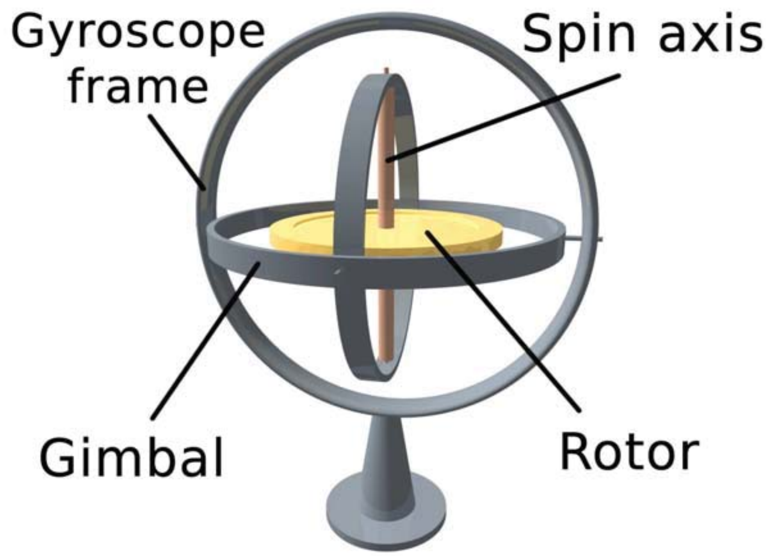


Figure A-5 Gyroscope

Note. From "3D Gyroscope", *Wikimedia*. Retrieved November 18, 2008, from http://upload.wikimedia.org/wikipedia/commons/e/e2/3D_Gyroscope.png

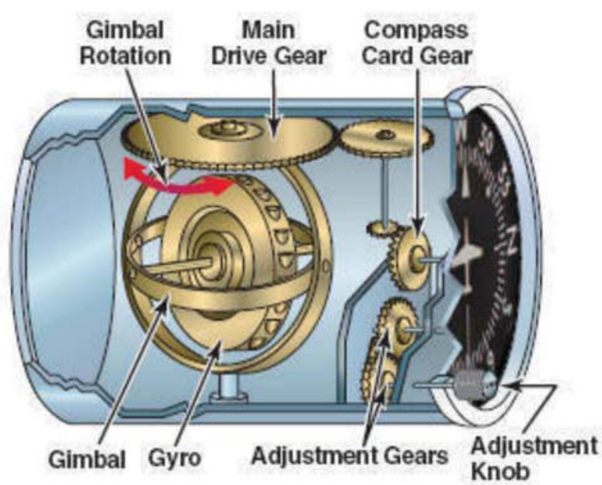


Figure A-6 Heading Indicator

Note. From "The Journal for the Proficient Pilot", *Over the Airwaves*. Retrieved November 18, 2008, from http://overtheairwaves.com/vol3-46.jpg

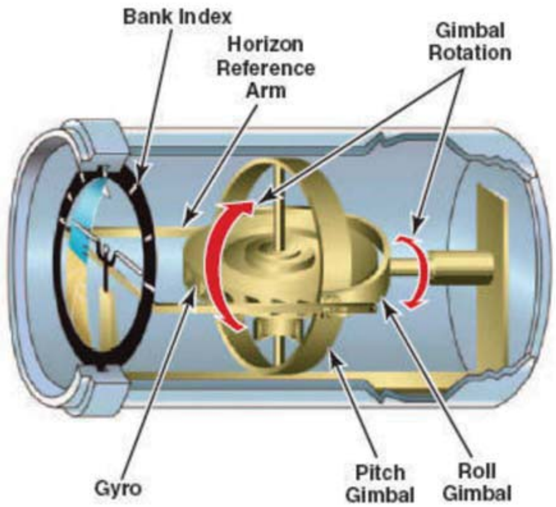


Figure A-7 Attitude Indicator

Note. From "The Journal for the Proficient Pilot", *Over the Airwaves*. Retrieved November 18, 2008, from http://overtheairwaves.com/vol3-45.jpg

Figure A-8 Turn and Bank Indicator

Note. From "Turn and Bank Indicator", *Integrated Publishing*. Retrieved November 18, 2008, from http://www.tpub.com/content/aviation/14014/img/14014_164_2.jpg

Figure A-9 Turn Co-ordinator

Note. From "More Instruments", *Wings and Wheels*. Retrieved November 18, 2008, from http://www.wingsandwheels.com/images/turn%20coordinator.gif

Figure A-10 AOA Indicator

Note. From "Stall/Spin", *AOPA Online*. Retrieved November 18, 2008, from http://www.aopa.org/images/asf/tn_spin_9.jpg

Figure A-11 Mach Indicator

Note. From "Mach Airspeed Indicator (MASI)", *Innovative Solutions and Support*. Retrieved November 18, 2008, http://www.innovative-ss.com/media/images/masi2.gif

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SAMPLE QUESTIONS

Set the specific training aid to the desired reading. Allow a team to provide an answer. Use a different instrument for each question.

ASI Questions

For each question, set the ASI training aid to the desired value. These can be asked in any order.

125 kt
65 kt
40 kt
75 kt
180 kt
210 kt
98 kt
110 kt
55 kt

VSI Questions

For each question, set the VSI training aid to the desired value. These can be asked in any order.

+200 feet per minute
+300 feet per minute
+150 feet per minute
+500 feet per minute
+800 feet per minute
-1000 feet per minute
-250 feet per minute
-900 feet per minute
-1200 feet per minute

Altimeter Questions

For each question, set the altimeter training aid to the desired value. These can be asked in any order.

8 900 feet
1 300 feet
2 600 feet
11 000 feet
1 250 feet
600 feet
400 feet
300 feet
1 000 feet

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INSTRUCTIONS FOR CREATION OF PITOT STATIC INSTRUCTIONAL AIDS

Resources

- One sheet of bristol board per training aid,
- One brass Acco fastener per training aid,
- Pencil,
- Compass from a geometry set,
- Ruler or straight edge,
- Coloured markers, and
- White bristol board.

Instructions – ASI

1. Draw a representation of an ASI in the centre of the bristol board. Include all of the numbers and coloured arcs / lines. Use Figure A-2 as a guide.
2. Colour the arcs and lines with the appropriate colours (white arc, green arc, yellow arc and red line).
3. Cut out a dial hand from the white bristol board.
4. Attach the dial hand to the centre of the ASI using the brass Acco fastener.
5. Ensure that the hand can move when needed, but that there is enough friction to keep it from moving on its own.

Instructions – Altimeter

1. Draw a representation of an altimeter's face in the centre of the bristol board. Include all of the numbers and graduated lines between the numbers. Use Figure A-3 as a guide.
2. Colour the altimeter. To add variety of colour, use yellow and black for the polygon shape under the hands' pivot point.
3. Cut dial hands from the white bristol board to represent the hands of an altimeter.
4. Attach the hands to the centre of the altimeter using the brass Acco fastener.
5. Ensure that the hands can move when needed, but that there is enough friction to keep them from moving on their own.

Instructions – VSI

1. Draw a representation of a VSI in the centre of the bristol board. Include all of the numbers on the positive and negative scales. Ensure that zero is located on the left side. Use Figure A-4 as a guide.
2. Colour the VSI.
3. Cut out a dial hand from the white bristol board.
4. Attach the hand to the centre of the VSI using the brass Acco fastener.
5. Ensure that the hand can move when needed, but that there is enough friction to keep it from moving on its own.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 3

EO C431.01 – EXPLAIN FLIGHT PERFORMANCE FACTORS

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare handouts for each cadet and slides of the figures located at Attachment A.

Obtain a model aircraft with articulated control surfaces and flaps for use in TPs 1–5.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize and summarize flight performance factors.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain flight performance factors.

IMPORTANCE

It is important for cadets to be able to explain flight performance factors as they apply to all stages of flight. Being able to explain flight performance factors provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Use the model aircraft with articulated control surfaces and flaps throughout this lesson to illustrate flight performance factors as they are discussed.

Provide a handout of the figures to each cadet located at Attachment A.

Teaching Point 1	**Explain left turning tendencies.**
Time: 15 min	Method: Interactive Lecture

LEFT TURNING TENDENCIES

Most airplane engines turn the propeller in a clockwise direction (as seen from the pilot's seat). As a result of four different factors, this produces a tendency for the airplane to turn left. These tendencies must be factored into the design of the airplane or corrected by the pilot.

Torque

Show the slide of Figure A-1 to the cadets.

Newton's Third Law of Motion states that every action has an equal and opposite reaction. This means that the clockwise rotation of the propeller is counteracted by a counter-clockwise rotation of the airplane. This reaction tends to force the left wing downwards, producing a tendency to turn left.

To correct this, airplanes can be designed with a right turning tendency, typically by having a slightly greater angle of incidence on the left wing. During takeoff (when the engine is usually running at full power) additional corrections must be applied by the pilot (rudder and / or ailerons) because of the increased amount of torque.

Asymmetric Thrust

Show the slide of Figure A-2 to the cadets.

At high angles of attack and high power settings (eg, takeoff) the blade of the propeller that is travelling down (the blade on the right) has a greater angle of attack than the blade that is travelling up. This creates more thrust from the right side of the propeller and creates a tendency for the aircraft to yaw or turn left.

To correct for asymmetric thrust (also known as P Factor), the pilot uses right rudder.

Precession

Show the slide of Figure A-3 to the cadets.

The spinning propeller acts like a gyroscope and tends to stay in the same plane of rotation, and resists any change to the plane. When a perpendicular force is applied to change the plane, a resultant force called precession is the result.

The force of precession is ahead of the plane of rotation and 90 degrees to the original applied force. Precession occurs in airplanes when the tail is lifted or lowered (eg, takeoff in a tailwheel aircraft).

To correct for precession, the pilot uses right rudder.

Slipstream

Show the slide of Figure A-4 to the cadets.

The air being pushed backwards by the propeller has a corkscrew motion and is called the slipstream. This causes more pressure on the left side of the fuselage and tail, and results in a tendency for the airplane to turn left.

The effects of the slipstream can be corrected by having the engine thrust line offset to the right, and / or by offsetting the vertical fin. When the airspeed of the airplane is low (eg, takeoff) the pilot may have to apply right rudder.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What four factors contribute to an airplane's left turning tendency?

Q2. Which propeller blade has a greater angle of attack at high angles of attack?

Q3. Which factor produces more pressure on the left side of the fuselage and tail?

ANTICIPATED ANSWERS:

A1. Torque, asymmetric thrust, precession, and slipstream.

A2. The blade moving downwards.

A3. Slipstream.

Teaching Point 2	**Explain climbs and glides.**
Time: 10 min	Method: Interactive Lecture

CLIMBS

During level flight at a constant airspeed, the engine produces thrust equal to drag, and the wings produce lift equal to weight. A pilot can initiate a climb by increasing the angle of attack (eg, pulling back on the stick) to produce more lift. The aircraft will climb but the airspeed will decrease.

Show the slide of Figure A-5 to the cadets.

The pilot could also initiate a climb by increasing the power setting of the engine (which would cause an increase in airspeed). If the angle of attack is not changed, the increased airspeed will create additional lift and the airplane will climb.

Once the climb is established, the aircraft is again in equilibrium. The attitude of the aircraft creates a rearward component of weight. In this state, thrust must equal drag plus the rearward component of weight and lift must equal weight, less its rearward component.

The extra power available from the engine to overcome the rearward component of weight determines the aircraft's ability to climb. As the altitude of the airplane increases, the air becomes less dense, and the available power of the engine decreases. The climb angle is reduced and further climbing eventually becomes impossible. The altitude at which this occurs is the absolute ceiling of the airplane.

Best rate of climb (V_Y). The rate of climb that gains the most altitude in the least amount of time. It is normally used during takeoff after all obstacles have been cleared.

Best angle of climb (V_X). The angle of climb that gains the most altitude in a given distance. It is used during takeoff to clear obstacles at the departure end of the runway.

Normal climb (cruise climb). The rate of climb recommended for prolonged climbs. It provides better cooling, visibility, and control compared to V_Y.

GLIDES

Show the slide of Figure A-6 to the cadets.

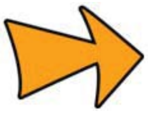
During a glide, the engine is producing minimal power and the airplane is influenced by gravity. In this state, equilibrium is achieved by balancing lift, weight, and drag.

To increase airspeed, the angle of the glide must be increased. Reducing airspeed creates a shallower glide, until the point of a stall.

A windmilling propeller (the propeller is being spun by the relative wind, not the power of the engine) can reduce the gliding distance by approximately 20 percent. Although getting the propeller to stop can increase the gliding range, it is difficult to perform. Additionally, the chances of restarting the engine are improved if the propeller is windmilling.

Best glide speed for range (maximum lift / drag). The airspeed which allows the aircraft to glide the farthest distance for altitude lost.

Best glide speed for endurance (minimum sink). The airspeed which allows the aircraft to remain in the air for the longest period of time.



Most airplane pilots are only concerned with the best glide speed for range airspeed as it is the airspeed usually used after an engine failure.

Sailplane (glider) pilots are concerned with both airspeeds. They use the minimum sink speed to remain in an area of rising air for as long as possible to extend the time of the flight.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is V_Y?

Q2. What is V_X?

Q3. What three forces must be balanced during a glide to achieve equilibrium?

ANTICIPATED ANSWERS:

A1. Best rate of climb.

A2. Best angle of climb.

A3. Lift, weight, and drag.

Teaching Point 3	**Explain turns.**
Time: 5 min	Method: Interactive Lecture

TURNS

Show the slide of Figure A-7 to the cadets.

In straight and level flight, the lift created by the wings is acting perpendicular to the wing span (vertically). To turn the aircraft, the pilot uses the ailerons to bank the aircraft in the direction of the desired turn. The lift is acting perpendicular to the wing span, but has both a horizontal and vertical component. It is the horizontal component of the lift (known as the centripetal force) that makes the aircraft turn. The opposing force (known as the centrifugal force) pulls the aircraft to the outside of the turn.

To maintain a constant altitude, the vertical component of lift must remain equal to the weight of the aircraft. This can be accomplished by increasing the angle of attack or the airspeed (by adding power). If the angle of attack is increased, additional power must be added to maintain the desired airspeed. The steeper the angle of bank, the more the angle of attack and power must be increased to maintain altitude.

At any given airspeed, a steeper angle of bank produces:

- a higher rate of turn,
- a lower radius of turn,
- a higher stalling speed, and
- a higher load factor (G load).

At any given angle of bank, a higher airspeed produces:

- a lower rate of turn, and
- a larger radius of turn.

Load Factors in Turns

Show the slide of Figure A-8 to the cadets.

Turns increase the load factor. The steeper the angle of bank, the higher the load factor is. For example, a 60-degree bank produces a load factor of two. This means an aircraft that weighs 2 500 kg will have an equivalent weight of 5 000 kg. Very steep turns can produce very high load factors and may lead to structural failure.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. Which component of lift makes the aircraft turn when it is banked?

Q2. What is the name of the force that pulls the aircraft towards the outside of the turn?

Q3. At any given airspeed, what does a steeper angle of bank produce?

ANTICIPATED ANSWERS:

A1. The horizontal component (centripetal force).

A2. The centrifugal force.

A3. A steeper angle of bank produces:

- higher rate of turn,
- lower radius of turn,
- higher stalling speed, and
- higher load factor (G load).

Teaching Point 4	**Explain stalls, spins, and spirals.**
Time: 15 min	Method: Interactive Lecture

STALLS

Show the slide of Figure A-9 to the cadets.

At low angles of attack, the air flows smoothly over the wing. As the angle of attack increases, the separation point between the laminar area and the turbulent area moves forward. At the critical angle of attack (determined by the design of the airfoil) the laminar flow separates from the wing and a large loss of lift (called a stall) occurs.

An airplane will stall:

- if the critical angle of attack is exceeded,
- at any airspeed if the critical angle of attack is exceeded, and
- at any attitude if the critical angle of attack is exceeded.

Symptoms of a Stall

As a stall is approached, there is usually a light buffeting of the airframe and controls. Lateral control of the aircraft is reduced as the ailerons lose their effectiveness in the separated airflow. When the stall is reached, lift is lost and the nose of the airplane drops.

A stall occurs gradually on most airplanes, giving the pilot time to recognize and react to the symptoms. If there is wash-out designed in the wing, the wing root will stall first and the ailerons will still be effective in the early stages of the stall.

Factors Affecting Stalls

Weight. Increasing the weight of an airplane increases the indicated airspeed at which it will stall.

Centre of gravity. Moving the centre of gravity forward increases the indicated airspeed at which the airplane will stall. Moving the centre of gravity rearward decreases the indicated airspeed at which it will stall. Moving the centre of gravity beyond the design limits will affect handling, stability, stall characteristics, and stall recovery.

Turbulence. An upward gust increases the angle of attack of the wing and could cause the airplane to exceed the critical angle at a lower airspeed than would be expected in calm air.

Show the slide of Figure A-10 to the cadets.

Turns. As the angle of bank in a turn is increased, the load factor and stalling speed increase. The stall speed in a turn can be calculated by multiplying the normal stall speed by the square root of the load factor.

Flaps. Increase the lift produced by the wing and lower the indicated airspeed at which the airplane will stall.

Snow, frost and ice. Accumulations on the wing (including dirt and bugs) disrupt the airflow and add additional weight (especially accumulations of ice) causing an increase in the airspeed at which the airplane will stall and a lower critical angle of attack.

Heavy rain. Increases the airspeed at which an airplane will stall as the water forms a film over the surface of the wing. Raindrops create craters and waves in the film, reducing lift and increasing drag, much like frost does.

Stall Recovery

To recover from the stall, the wing has to produce sufficient lift. In general, the stall recovery for most light aircraft involves reducing the angle of attack (below the critical angle of attack). Applying power to increase the airspeed may also be part of the recovery process.

The pilot operating handbook (POH) for most light aircraft lists the following steps to recover from a stall:

1. Reduce the angle of attack by moving the control column forward.
2. Apply power to increase the airspeed.
3. Return to level flight.

SPINS

Show the slide of Figure A-11 to the cadets.

A spin may develop after a stall if one wing becomes disturbed and produces a different amount of lift. This may happen as a result of using ailerons, applying rudder to produce yaw, entering a stall in a banked attitude, or movement of a wing by turbulent air.

When one wing drops, it has a larger angle of attack and produces less lift (as it has already stalled) compared to the wing that is moving up which has a smaller angle of attack. This difference accelerates the rolling motion and autorotation sets in.

Show the slide of Figure A-12 to the cadets.

Stages of a Spin

A spin has three stages:

1. incipient,
2. developed, and
3. recovery.

The incipient stage occurs from the time the airplane stalls and rotation starts until the spin axis becomes vertical or nearly vertical.

In the developed stage, the angles and motions of the airplane are stabilized and the flight path is nearly vertical. During this stage the airspeed has stabilized.

> A spin is a stalled condition with a constant airspeed during the developed stage.

Spin characteristics are different for different aircraft so the technique for recovery from the specific POH must be followed. In the absence of recommendations from the manufacturer, most light airplanes can be brought out of a spin by following these steps:

1. Decrease power to idle and neutralize ailerons.
2. Apply full rudder in the opposite direction of the rotation.
3. Move the control column forward to reduce the angle of attack and unstall the wings.
4. When rotation stops, neutralize the rudder, level the wings, and ease out of the dive.

SPIRALS

A spiral is a steep descending turn in which the aircraft rapidly loses altitude while the airspeed rapidly increases.

The characteristics of a spiral include:

- excessive angle of bank,
- rapidly increasing airspeed, and
- rapidly increasing rate of descent.

The recovery process for a spiral is as follows:

1. Decrease power to idle and level the wings simultaneously with coordinated use of rudder and ailerons.
2. Ease out of the dive.
3. Apply power as required to maintain altitude.

> A spiral is not a stalled condition. An improper recovery can cause an excessive load factor and lead to structural failure.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS:

Q1. What must be exceeded in order for a stall to occur?

Q2. What does the stall speed do as the angle of bank in a turn is increased?

Q3. What is the difference between a spin and a spiral?

ANTICIPATED ANSWERS:

A1. The critical angle of attack.

A2. The stall speed increases.

A3. A spin is a stalled condition and has a constant airspeed. A spiral is not a stalled condition and has a rapidly increasing airspeed.

Teaching Point 5	**Explain airspeed limitations.**
Time: 5 min	Method: Interactive Lecture

To reduce the risk of structural failure from an excessive load factor, airplane manufacturers publish a number of airspeed limitations in the POH.

Never exceed (maximum permissible dive) speed (V_{NE}). The maximum airspeed at which the airplane may be operated in smooth air.

Maximum structural cruise (normal operating limit) speed (V_{NO}). The maximum cruise airspeed at which the airplane was designed to operate.

Manoeuvring speed (V_A). The maximum airspeed at which the flight controls can be fully deflected without causing structural damage.

Maximum gust intensity speed (V_B). The maximum airspeed for penetration of gusts of maximum intensity. For most light airplanes V_A and V_B are the same.

Maximum flaps extended speed (V_{FE}). The maximum airspeed at which the airplane may be operated with the flaps extended.

CONFIRMATION OF TEACHING POINT 5

QUESTIONS:

Q1. What does V_{NE} specify?

Q2. What is the maximum airspeed at which the flight controls can be fully deflected?

Q3. What does V_{FE} specify?

ANTICIPATED ANSWERS:

A1. The maximum airspeed at which the airplane may be operated in smooth air.

A2. V_A.

A3. The maximum airspeed at which the airplane may be operated with the flaps extended.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What happens to the load factor in a turn?

Q2. What are the characteristics of a spiral?

Q3. What is the maximum cruise airspeed at which the airplane was designed to operate?

ANTICIPATED ANSWERS:

A1. The load factor increases.

A2. The characteristics of a spiral include:

- excessive angle of bank,
- rapidly increasing airspeed, and
- rapidly increasing rate of descent.

A3. V_{NO}.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Future aviation training and instructional duties depend on knowledge of left turning tendencies, climbs, glides, turns, stalls, spins, spirals and airspeed limitations.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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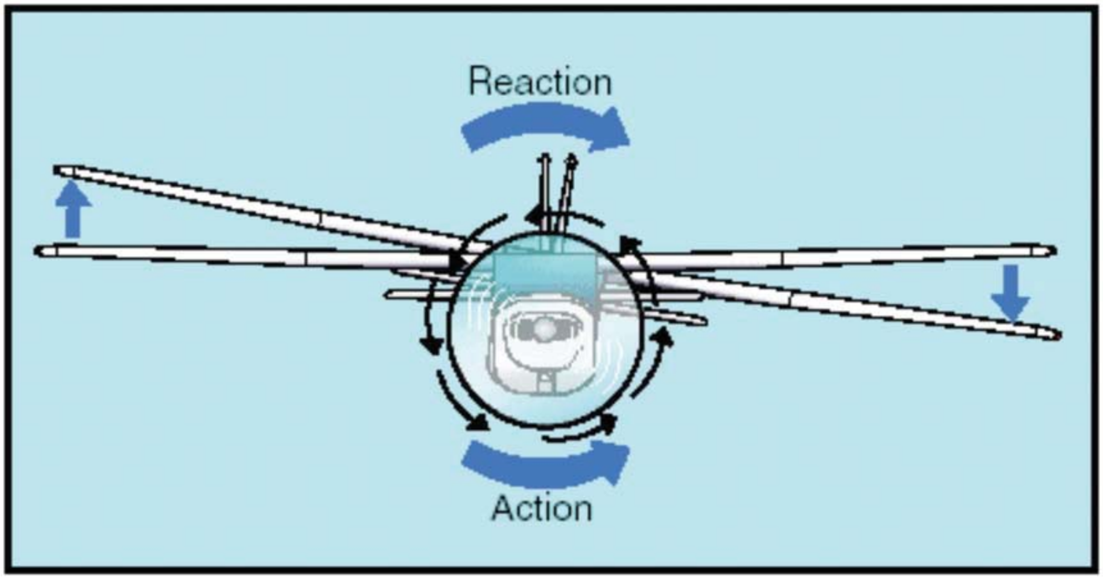

Figure A-1 Torque Reaction

Note. From “Propeller Aerodynamics”, *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/propeller-aerodynamics.html

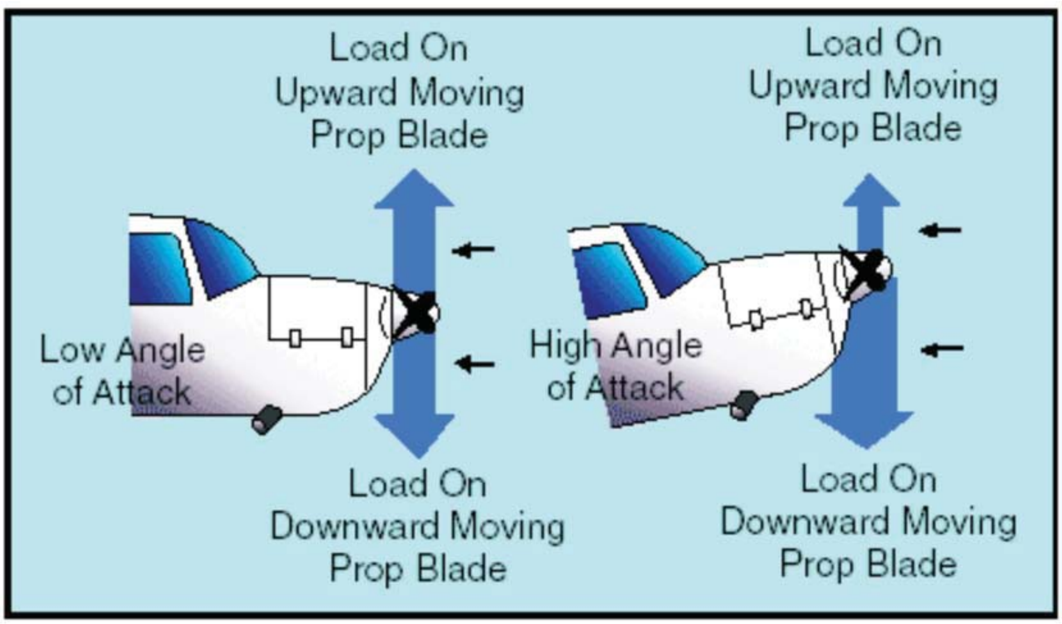

Figure A-2 Asymmetric Thrust (P Factor)

Note. From “Propeller Aerodynamics”, *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/propeller-aerodynamics.html

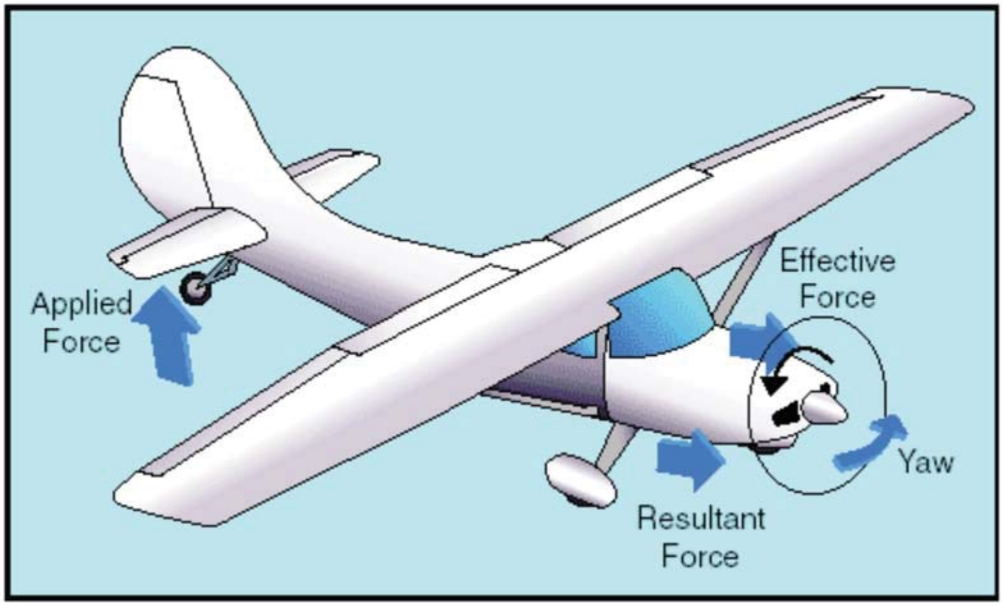

Figure A-3 Precession When the Tail is Lifted

Note. From “Propeller Aerodynamics”, *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/propeller-aerodynamics.html

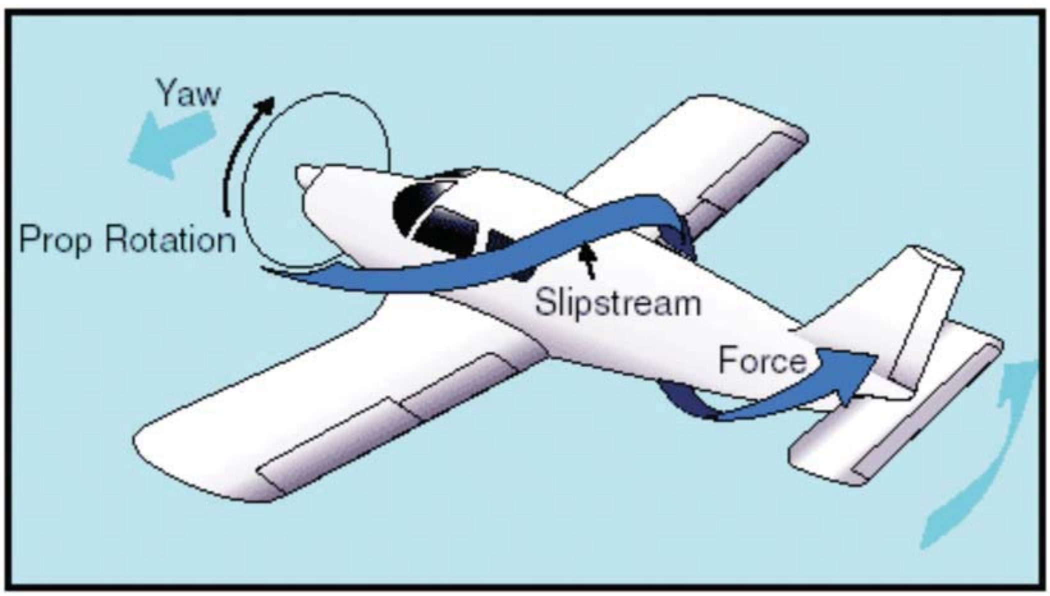

Figure A-4 Slipstream

Note. From “Propeller Aerodynamics”, *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/propeller-aerodynamics.html

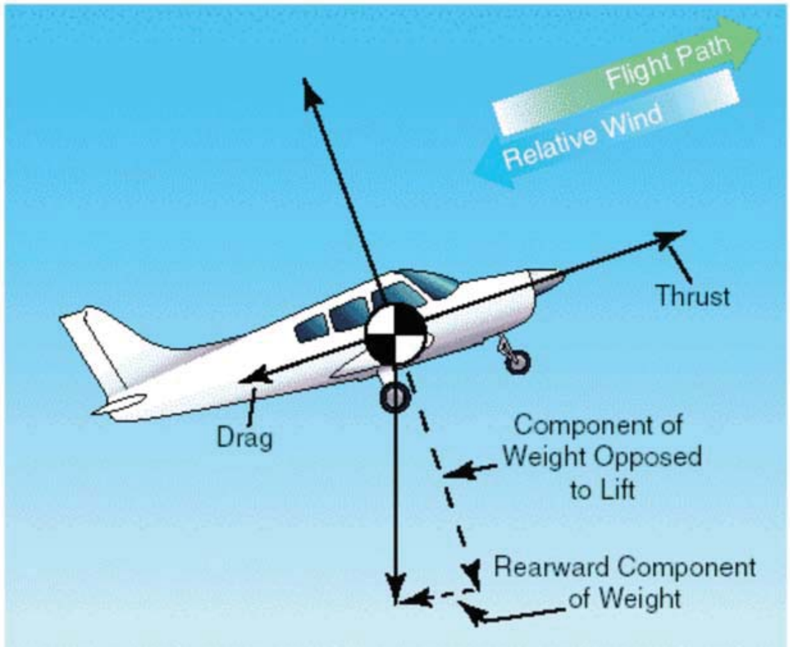

Figure A-5 Forces in a Climb

Note. From “Aerodynamics in Flight”, *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/Aerodynamics_in_flight.html

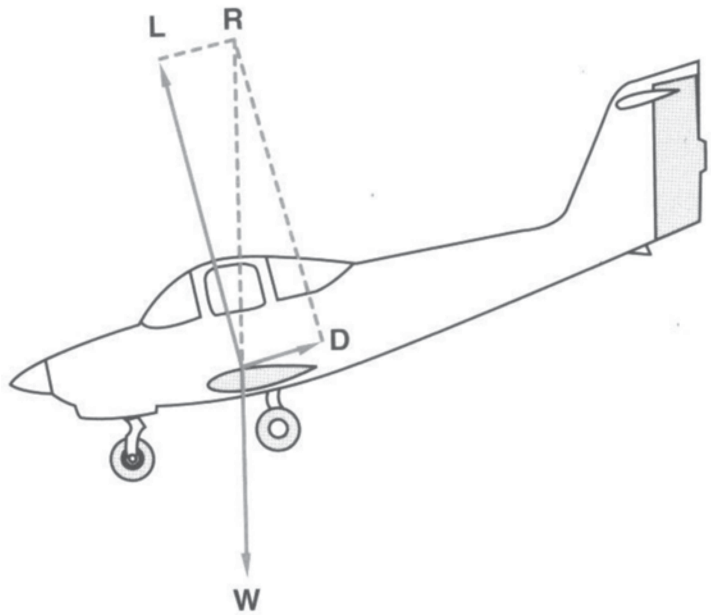

Figure A-6 Forces in a Glide

Note. From *From the Ground Up: Millennium Edition* (p. 34), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

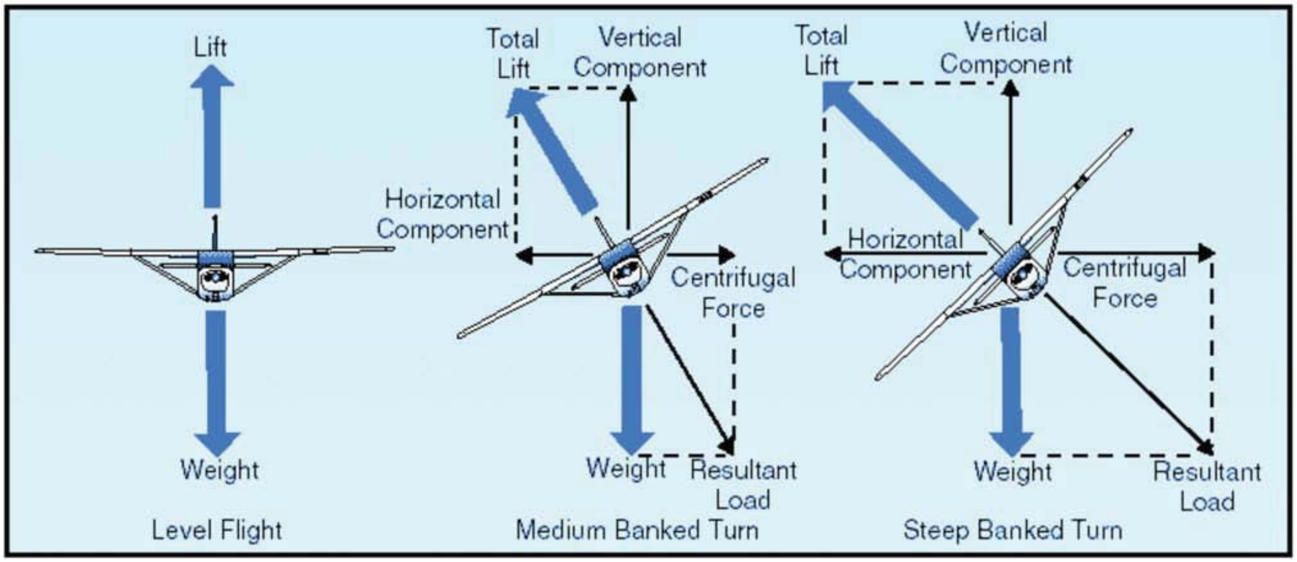

Figure A-7 Forces in a Turn

Note. From "Aerodynamics in Flight", *Free Online Private Pilot Ground School*. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/Aerodynamics_in_flight.html

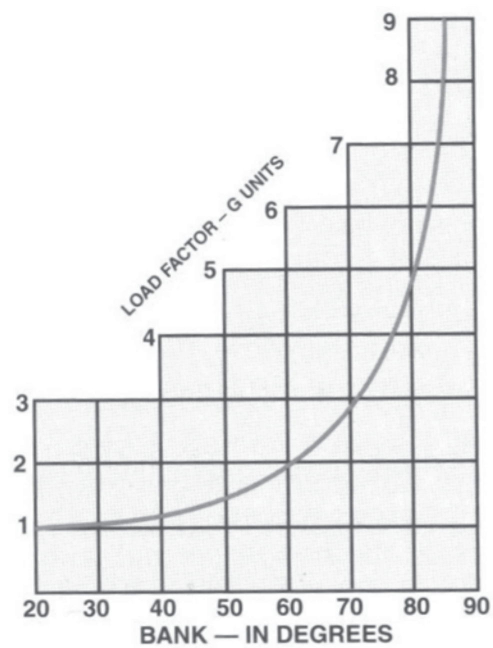

Figure A-8 Load Factors in Turns

Note. From *From the Ground Up: Millennium Edition* (p. 35), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

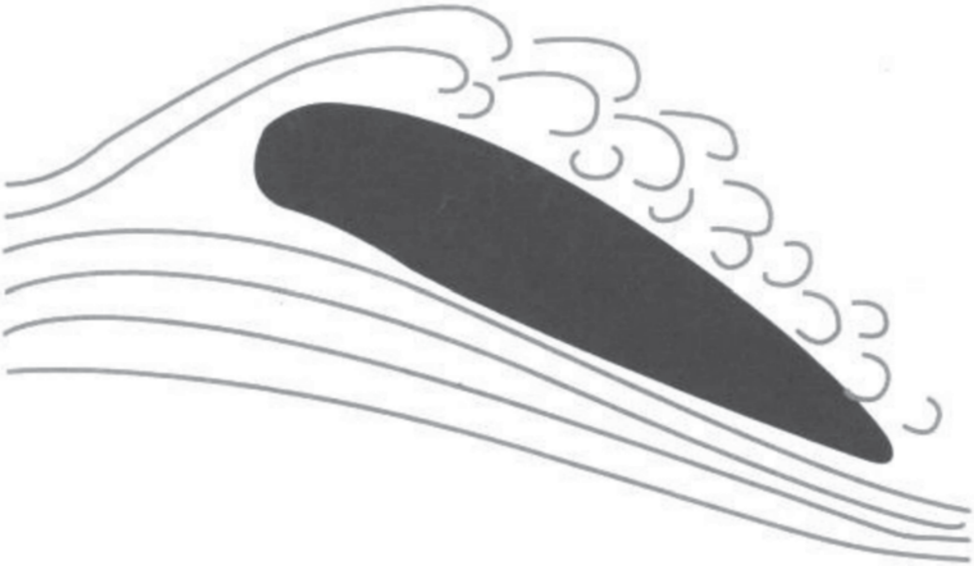

Figure A-9 Stall

Note. From *From the Ground Up: Millennium Edition* (p. 35), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

STALL SPEED, POWER OFF			
GROSS WEIGHT 2800 LBS.	ANGLE OF BANK		
CONFIGURATION	0°	30°	60°
FLAPS UP	64	69	91
FLAPS 20°	57	61	81
FLAPS 40°	55	59	78

Figure A-10 Stall Speed in Turns

Note. From *From the Ground Up: Millennium Edition* (p. 35), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

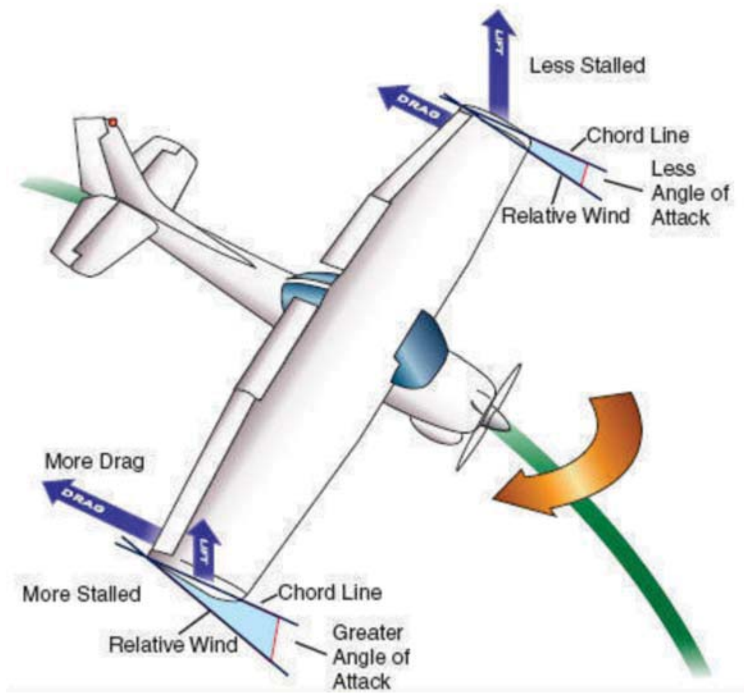

Figure A-11 Spin

Note. From “What is a Spin?”, *Over the Airwaves*. Retrieved November 12, 2008, from http://overtheairwaves.com/Vol3-111.jpg

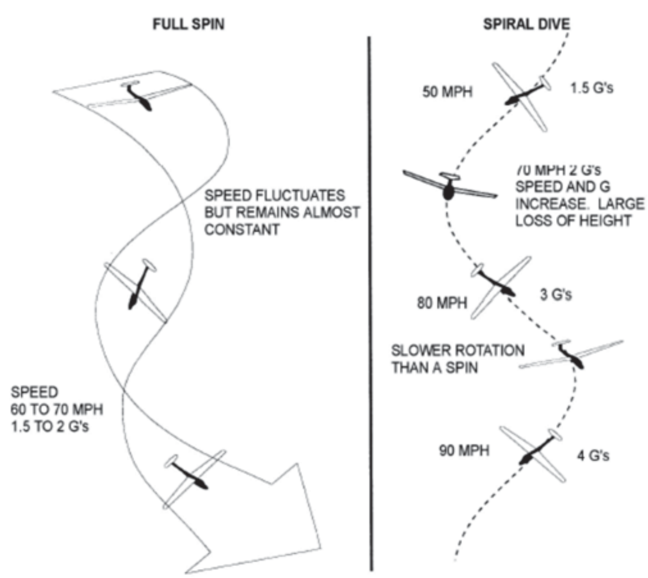

Figure A-12 Spin and Spiral Recognition

Note. From *Air Cadet Gliding Program Manual* (p. 6-6-4), by Air Force Training, 2009, Ottawa, ON: Department of National Defence.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 4

EO C431.02 – DEMONSTRATE TURNS, CLIMBS AND DESCENTS IN A FLIGHT SIMULATOR

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy the handouts located at Attachments A and B for each cadet.

Create a scenario (eg, location, weather, aircraft) for the aircraft flight simulator IAW the manual provided with the software.

Set up the simulator with the scenario created.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to give direction on procedures and present basic or background information about flight simulation.

A demonstration and performance was chosen for TP 3 as it allows the instructor to explain and demonstrate turns, climbs and descents in a flight simulator while providing an opportunity for the cadets to practice the skills under supervision.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have demonstrated turns, climbs and descents in a flight simulator.

IMPORTANCE

It is important for cadets to demonstrate turns, climbs and descents in a flight simulator to develop a better understanding of the principles of flight and stimulate an interest in aviation. This will also serve as a solid foundation for any cadet who participates in a demonstration flight or flying training in the future.

Teaching Point 1	Explain any safety considerations related to the location or design of the flight simulator.
Time: 5 min	Method: Interactive Lecture

Arrange the cadets so they can hear the safety briefing prior to using the flight simulator.

This briefing is being conducted to pass on safety considerations for use of the flight simulator. The actual content of the briefing will vary by region and squadron based on the squadron assets, the location of the assets, and other environmental factors. However, the following should be covered:

- DND regulations concerning the appropriate use of computers, including:
  - CATO 11-07, *Internet Acceptable Use–Cadet Program*,
  - DAOD 6001, *Internet*, and
  - Regional Orders;
- location of the nearest fire exit in case of fire,
- awareness of any moving parts of the simulator, and
- proper entry and exit techniques to avoid damage to assets.

CONFIRMATION OF TEACHING POINT 1

Confirmation questions for this TP will depend on the content covered.

Teaching Point 2	Explain how to manipulate the necessary control inputs and the location of necessary instruments.
Time: 10 min	Method: Interactive Lecture

NECESSARY CONTROL INPUTS

Control Column or Yoke

Using a control yoke in a flight simulator is preferable. Accordingly, the following will need to be adjusted if a control column is used instead.

The control yoke is located directly in front of the pilot in the centre of the pilot's side of the instrument panel. The control yoke is very much like the steering wheel of a car, both in look and function. The yoke is designed to move on two planes of motion.

The first plane of motion is left and right. The control yoke will usually move to approximately 45 degrees left or right of centre when moved like a steering wheel. This motion is what controls the ailerons of the simulated airplane. To roll left, turn the yoke left. To roll right, turn the yoke right. Remember, this must be used as well as the rudder in order to properly turn the aircraft.

The control yoke also moves back and forth. The steering column of the yoke moves in and out of the main assembly. This controls the elevator of the simulated aircraft. To pitch up, pull back (towards the pilot). To pitch down, push forward (away from the pilot).

Pitch will change the altitude, but more importantly the airspeed.

Rudder Pedals

On the floor of the simulator there are two pedals. If the left pedal is pushed forward, the right one moves back and vice versa. These pedals control the rudder of the simulated aircraft. To yaw left, push on the left pedal. To yaw right, push on the right pedal.

Rudder pedals move in different directions so pressure must be taken off the opposite pedal in order for the movement to take place.

LOCATION OF NECESSARY INSTRUMENTS

Distribute the handout located at Attachment A to each cadet.

The instruments of the simulated aircraft will be displayed in front of the pilot, laid out above the control yoke on what is called an instrument panel. The four instruments that are of significance are the airspeed indicator (ASI), vertical speed indicator (VSI), altimeter, and turn coordinator.

ASI. Shows an aircraft's speed through the air.

VSI. Shows the rate at which an aircraft is ascending or descending.

Altimeter. Shows the altitude of an aircraft.

Turn Coordinator. Shows rate of roll as well as the rate of turn of the aircraft.

Function of the ASI, VSI, altimeter and turn coordinator was discussed in M431.02 (Describe Flight Instruments).

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. Where is the control yoke located?

Q2. Where are the instruments located?

Q3. How is pitch controlled?

ANTICIPATED ANSWERS:

A1. Directly in front of the pilot in the centre of the pilot's side of the instrument panel.

A2. In front of the pilot, laid out above the control yoke on what is called an instrument panel.

A3. By moving the yoke towards or away from the pilot.

Teaching Point 3	Explain, demonstrate and have the cadets practice turns, climbs and descents using a flight simulator.
Time: 70 min	Method: Demonstration and Performance

ACTIVITY

OBJECTIVE

The objective of this activity is to allow the cadets to practice turns, climbs and descents and witness their effect on the pitot static instruments and the turn coordinator.

RESOURCES

- flight simulator (Microsoft flight simulator, computer, control yoke, and rudder pedals; or Link),
- scenario using a local airport, no weather, and positioned 1 000 feet above ground level (AGL), and
- Climbs, Turns and Descents Handout located at Attachment B.

ACTIVITY LAYOUT

Training should be conducted for a light training single engine aircraft such as:

- a Cessna 172, or
- a Piper J-3C-65 Cub.

This will depend on the location of the flight simulator.

ACTIVITY INSTRUCTIONS

1. Start the simulator with the scenario created prior to the lesson.
2. Using the flight simulator, explain and demonstrate turns, climbs and descents by climbing to 5 000 feet AGL, making turns and descending to 1 000 feet AGL.

Specific details on how to conduct turns, climbs and descents can be found in:

- the Transport Canada *Flight Training Manual*,
- the *Computerized Aircraft Simulation Center*,
- the Pilots Operating Handbook (POH), and / or
- the operating instructions for the flight simulator program.

3. Distribute the handout located at Attachment B to each cadet. The handout reflects the sequence in which the instructor will explain and demonstrate turns, climbs and descents.
4. Have the cadets take turns in the flight simulator, practicing turns, climbs and descents as demonstrated.
5. Give each cadet verbal and physical assistance as necessary as they practice turns, climbs and descents.
6. Provide each cadet an equal amount of time. This means that the 70 minutes should be divided as evenly as possible based on the number of cadets in the class and the number of flight simulators available.
7. Debrief each cadet as they finish their individual flight. The debrief should include the following:
   a. the overall performance of the cadet,
   b. the sequences where the cadet performed strongly,
   c. the sequences where the cadet performed weakly, and
   d. how to improve their performance.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in practicing turns, climbs and descents in the flight simulator will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

It has been stated by many flight instructors that a significant difference can be seen in the quality of students who used a flight simulator compared to those who did not. The military is a large user of computer-based flight simulators, as are Air Canada and WestJet. Continued training on flight simulators will enhance preparation for future flight training.

INSTRUCTOR NOTES / REMARKS

All staff should be familiarized with the operation of the flight simulator prior to the cadets arriving. This will allow them to troubleshoot, and give them a better perspective for instructing.

Additional instructors are required for this lesson. There should be one instructor per two flight simulators.

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-139 ISBN 0-7715511-5-0 Transport Canada. (1999). *Flight training manual 4th edition revised*. Ottawa, ON: Transport Canada.

C3-156 *Computerized Aircraft Simulation Center*. (2007). Retrieved October 2, 2007, from http://www.regions.cadets.forces.gc.ca/pac/aircad/flight/casc_lessons_e.asp

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Figure A-1 Cessna Flight Instrument Panel

Note. From "Design a Virtual Cockpit Instrument Panel", Ngee Ann Polytechnic, 2007. Retrieved October 31, 2007, from http://www.learnerstogether.net/avionics-project-design-problem-based-learning/56

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CLIMBS, TURNS AND DESCENTS HANDOUT

The handout is presented to reflect the sequence in which the instructor will explain and demonstrate climbs, turns and descents.

CLIMBS

Climbs are executed by doing the following:

1. Adjust the pitch angle to obtain climb airspeed.
2. Increase the power to maintain airspeed.
3. Climb to the desired altitude.
4. Upon reaching the desired altitude, resume a level attitude and adjust power to maintain altitude and airspeed.
5. For any climb, follow the sequence: attitude, power, trim (APT).

TURNS

Turns are executed by doing the following:

1. Look out from the outside to the inside of the turn. A good look out is the most important part of airmanship as is essential for safe flying.
2. Roll the airplane in the desired direction, using the rudder to stay coordinated. Stay coordinated by "stepping on the ball" of the turn coordinator. That is, if the ball of the turn coordinator is to the right, apply more right rudder and vice versa.
3. Once the desired angle of bank has been reached, reduce the yoke input as required to maintain that angle of bank.

Gentle turn. A turn with up to 15 degrees angle of bank.

Medium turn. A turn with approximately 30 degrees angle of bank.

Steep turn. A turn with at least 45 degrees angle of bank. When executing a steep turn, as the angle of bank passes 30 degrees, back-stick pressure must be applied to maintain attitude and altitude. The power setting must be increased to maintain altitude.

DESCENTS

Descents are executed by doing the following:

1. Decrease power, adjust the attitude to reach and maintain the descent speed, and adjust the trim.
2. For any descent, follow the sequence: power, attitude, trim (PAT).
3. Upon reaching the desired altitude, resume a level attitude and adjust power to maintain altitude and airspeed.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 5

EO C431.03 – FLY A RADIO-CONTROLLED AIRCRAFT

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Construct and / or assemble a radio-controlled aircraft for use by cadets.

Charge multiple batteries for use with radio-controlled aircraft.

Assistant instructors are required for this lesson.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

A practical activity was chosen for this lesson as it is an interactive way to introduce the cadets to flying a radio-controlled aircraft in a safe and controlled environment. This activity contributes to the development of skills and knowledge in a fun and challenging setting.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have flown a radio-controlled aircraft.

IMPORTANCE

It is important for cadets to fly a radio-controlled aircraft as it provides an opportunity to apply the principles of flight in a fun and practical way.

Teaching Point 1 — **IAW the instructions supplied with the radio-controlled aircraft and the Model Aeronautics Association of Canada (MAAC) safety code, have the cadet fly a radio-controlled aircraft.**

Time: 80 min — Method: Practical Activity

BACKGROUND KNOWLEDGE

Radio-Controlled Aircraft

Radio-controlled aircraft are more complicated and expensive than free-flight gliders or rubber-powered airplanes. They are an exciting way to apply the principles of flight in a practical way. They can be scratch-built from plans, built from kits, assembled from almost-ready-to-fly (ARF) kits, or assembled from ready-to-fly (RTF) packages.

Small, light-weight, electric-powered helicopters are also a viable alternative to a conventional radio-controlled airplane. They are available in different sizes in RTF packages and can be flown indoors in smaller spaces than required by an airplane. Most micro-helicopters on the market use counter-rotating main rotors that make a stable, easy-to-hover helicopter.

The Blade CX Series (CX, CX2, CX3 and MCX), from E-Flite are among the most popular entry-level helicopters. They come in an RTF package and include a radio transmitter-receiver combination that allows multiple aircraft to operate at the same time without interference.

Figures 1 and 2 show the Blade CX2 and Blade MCX, respectively.

When learning to operate a radio-controlled helicopter, it is recommended that a training gear set is attached to the landing skids to reduce rollovers as shown in Figure 3.

Ensure that there is an ample supply of spare parts (blades, shafts, and heads) available to repair any damages caused by a crash.

Having multiple batteries available (a minimum of three per helicopter) minimizes the time spent waiting while batteries are recharging.

Figure 1 Blade CX2

Note. From “Horizon Hobby”, *E-Flite Blade CX2*. Retrieved November 5, 2008, from http://www.horizonhobby.com/Products/Gallery.aspx?ProdID=EFLH1250&Index=0

Figure 2 Blade MCX

Note. From “Horizon Hobby”, *E-Flite Blade MCX*. Retrieved November 5, 2008, from http://www.horizonhobby.com/Products/Gallery.aspx?ProdID=EFLH2200&Index=4

Figure 3 Blade CX2 With Training Gear Installed

Note. From “Elite Models”, *Blade CX2*. Retrieved November 5, 2008, from http://www.elitemodelsonline.co.uk/Products/Helicopters/Helicopters+Spares/E-Flite/Blade+CX2

A radio-controlled airplane can be built easily and quickly from common materials such as corrugated plastic (commonly used for signs) and polyvinyl chloride (PVC) downspout. These simple plastic airplane designs (SPADs) are inexpensive and durable.

Information and free plans for SPADs can be found at http://www.spadtothebone.com

The Debonair is designed to be used as a trainer and is shown at Figure 4.

Figure 4 SPAD Debonair

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

RTF packages (containing an airframe, engine or motor, radio gear, and hardware) can be assembled in a few hours and generally contain almost everything needed to go flying except for field items such as:

- glue,
- starting equipment, and
- fuel / batteries.

> Figure 5 and 6 shows examples of an RTF aircraft suitable for first-time fliers. The Vapor Bind-N-Fly model also comes as the Vapor RTF model which includes the radio transmitter and is for indoor flying only.

Figure 5 Alpha 40 DSM2 RTF

Note. From “Hangar 9”, *Alpha 40 DSM2 RTF*. Retrieved November 5, 2008, from http://www.hangar-9.com/Products/Default.aspx?ProdID=HAN4400

Figure 6 Vapor Bind-N-Fly

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

Computer simulators for radio-controlled aircraft are available and can be used to provide training in a safe and controlled environment without having to worry about the cost and time associated with repairing an aircraft after a crash.

Most of the simulators available come with a "transmitter" that is almost identical to the ones used for real radio-controlled aircraft that plug into the computer through a USB port, and a set of CDs / DVDs to install the program.

Testimonials from many people indicate the number and severity of crashes are reduced by spending time on the simulator prior to flying the radio-controlled aircraft. Additionally, most simulators have many different radio-controlled aircraft included, which allows the pilot to experiment with various aircraft types.

Popular radio-controlled aircraft simulators include:

- RealFlight (Knife Edge Software), and
- FS One (Hangar 9).

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets fly a radio-controlled aircraft.

RESOURCES

If an aircraft has to be constructed before flying, complete by:

- setting up a desk or table for each cadet (or group of cadets);
- placing the required construction and / or assembly tools and materials on the tables;
- showing a completed model aircraft to the cadets;
- describing the parts and components of the model aircraft to the cadets; and
- having the cadets construct and / or assemble the model aircraft IAW the plans and / or instructions.

- Radio-controlled aircraft,
- Starting equipment,
- Fuel / batteries,
- Battery charger, and
- Transmitter.

ACTIVITY LAYOUT

Large indoor area (eg, gymnasium or drill hall) or a large outdoor area for flying a radio-controlled aircraft IAW regulations and safety guidelines set out by Model Aeronautics Association of Canada (MAAC).

ACTIVITY INSTRUCTIONS

1. Demonstrate to the cadets how to fly the radio-controlled aircraft to include:
   a. taking off;
   b. flying a circuit; and
   c. landing.
2. Have the cadets fly the radio-controlled aircraft IAW the plans and / or the instructions.

SAFETY

Assistant instructors will monitor the cadets to ensure they are following the instructor's directions and using all equipment safely.

All radio-controlled aircraft activities shall be conducted IAW the regulations and safety guidelines set out by MAAC.

Flying a radio-controlled aircraft should not be attempted without assistance from an experienced radio-controlled aircraft pilot. A list of MAAC sanctioned clubs can be found at http://www.maac.ca/clubs/maac_clubs_map.php.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in this activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in flying a radio-controlled aircraft will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Flying a radio-controlled aircraft is a fun and challenging way to apply the principles of flight.

INSTRUCTOR NOTES / REMARKS

It is recommended that the three periods required for this EO be scheduled consecutively.

The radio-controlled aircraft can be flown individually or in small groups of two to four cadets.

Assistant instructors are required for this lesson.

Suitable model aircraft may be chosen from the following:

- Blade CX2 / CX3 (radio-controlled electric helicopter),
- Blade MCX (radio-controlled electric helicopter),
- SPAD Debonair (radio-controlled airplane),
- Alpha 40 DSM2 RTF (radio-controlled airplane),
- Vapor Bind-N-Fly / RTF(radio-controlled airplane), and / or
- an alternate choice (or choices) selected by the squadron.

The helicopter being selected should have the counter-rotating rotor system with a 2.4 GHz radio transmitter.

Radio-controlled aircraft simulators such as RealFlight (Knife Edge Software) or FS One (Hangar 9) that run on a personal computer can also be used.

REFERENCES

C3-303 Model *Aeronautics Association of Canada Safety Code*. (2008). Retrieved February 5, 2009, from http://www.maac.ca/docs/2007/maac_safety_code_v008sept30_08_english.pdf

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 1

EO M432.01 – DESCRIBE FUEL SYSTEMS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

Photocopy the handout located at Attachment B for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize fuel systems.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described fuel systems.

IMPORTANCE

It is important for cadets to be able to describe fuel systems as a solid understanding of fuel systems provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1	**Describe fuel systems.**
Time: 10 min	Method: Interactive Lecture

THE FUEL SYSTEM

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

- normal flight,
- violent manoeuvres,
- sudden acceleration, and
- sudden deceleration.

Fuel systems include the following parts:

- fuel tanks,
- a fuel selector valve,
- fuel lines and filters,
- a fuel quantity gauge, and
- fuel primer.

Pressure-Feed System

Show slide of Figure A-1 to the cadets.

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

- the basic pump,
- auxiliary electric pumps for emergency situations,
- a booster pump to create the pressure required to start the fuel flowing before the engine is running, and
- the pressure gauge mounted on the cockpit panel used to read the pressure of fuel entering the carburetor.

Gravity-Feed System

Show slide of Figure A-2 to the cadets.

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

Fuel Selector Valve

The fuel selector valve is used by the pilot to select the desired fuel tank to draw fuel. The selector valve may also be used to shut off the flow of fuel from the tanks.

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

FUEL

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

Fuel Types

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

Octane. A substance which possesses minimum detonating qualities.

Heptane. A substance which possesses maximum detonating qualities.

Show slide of Figure A-3 to the cadets.

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

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

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

Grade 100 / 130 indicates:

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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What fuel-feed system does an aircraft with low-wing configuration use?

Q2. For what is the fuel selector valve used?

Q3. How are octane ratings of fuels calculated?

ANTICIPATED ANSWERS:

A1. An aircraft with low-wing configuration uses a pressure-feed system.

A2. The fuel selector valve is used by the pilot to select the desired fuel tank to draw fuel. The selector valve may also be used to shut off the flow of fuel from the tanks.

A3. Octane ratings of fuels are calculated as a ratio of octane and heptane.

Teaching Point 2	**Describe carburetors.**
Time: 10 min	Method: Interactive Lecture

CARBURETORS

Show slide of Figure A-4 to the cadets.

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

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

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

Float Carburetor

Show slide of Figure A-5 to the cadets.

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

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

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

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

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

Mixture Control

The correct fuel / air mixture will be obtained at sea level as carburetors are normally calibrated for sea level operation.

As altitude increases, the density of the air decreases and a given volume of air weighs less. The proportion of air by weight to that of fuel will become less although the volume remains the same. The mixture at higher altitude becomes over-rich causing fuel waste and loss of power.

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

The general rules when using a manual mixture control are:

- rich mixtures—high power settings, and
- leaner mixtures—cruise power settings.

Carburetor Icing

Show slide of Figure A-6 to the cadets.

Distribute the handout located at Attachment B to each cadet.

With temperatures ranging from minus 5 degrees Celsius to plus 30 degrees Celsius and under certain moist atmospheric conditions, ice can form in the induction system closing off the flow of fuel to the engine. Ice can form on various surfaces of the carburetor especially on the throttle.

Show slide of Figure A-7 to the cadets.

> Modern aircraft have incorporated a method of directing heated air into the carburetor air intake, activated by the carburetor hot air handle in the cockpit. This heated air can prevent ice from forming or melt ice that has already formed.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. How are the fuel / air proportions calculated?

Q2. What does the mixture control adjust?

Q3. What do modern aircraft have to melt ice that has formed?

ANTICIPATED ANSWERS:

A1. Fuel / air proportions are calculated by weight not volume.

A2. The mixture control adjusts the amount of fuel being drawn from the nozzle, restoring the proper fuel / air mix.

A3. Modern aircraft have incorporated a method of directing heated air into the carburetor air intake, activated by the carburetor hot air handle in the cockpit.

Teaching Point 3	**Describe fuel injection.**
Time: 5 min	Method: Interactive Lecture

FUEL INJECTION

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

Advantages of fuel injection include:

- more uniform distribution of fuel to all cylinders,
- better cooling, through the elimination of lean hot mixtures to some of the more distant cylinders,
- fuel saving through uniform distribution,
- increased power since the heat carburetor air is eliminated, and
- elimination of the hazard of carburetor icing.

> Throttle ice can occur when the temperature is less than 5 degrees Celsius.
> Impact ice can gather in bends in the system, impact tubes, and air filter.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What does the control valve do?

Q2. What are the advantages of fuel injection?

Q3. Where can impact ice gather?

ANTICIPATED ANSWERS:

A1. The control valve supplies pressurized fuel continuously to the induction system near the intake valve.

A2. Advantages of fuel injection include:

- more uniform distribution of fuel to all cylinders,
- better cooling, through the elimination of lean hot mixtures to some of the more distant cylinders,
- fuel saving through uniform distribution,
- increased power since the heat carburetor air is eliminated, and
- elimination of the hazard of carburetor icing

A3. Impact ice can gather in the system, impact tubes, and air filter.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What fuel-feed system does a high-wing, low-powered light aircraft use?

Q2. Why is leaning the engine both practical and economical?

Q3. When can throttle ice occur?

ANTICIPATED ANSWERS:

A1. A high-wing, low-powered light aircraft uses a gravity-feed system.

A2. It results in:

- better fuel economy lowering the cost of operation,
- a smoother running engine,
- a more efficient engine giving higher indicated airspeeds and better aircraft performance,
- extended range of the aircraft at cruise,
- less spark plug fouling and longer life for spark plugs,
- more desirable engine temperatures, and
- cleaner combustion chambers and less chance of pre-ignition from undesirable deposits.

A3. Throttle ice can occur when the temperature is less than 5 degrees Celsius.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Being able to describe fuel systems is important for understanding more complex material. A solid understanding of aero engines is required to pursue future aviation training.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

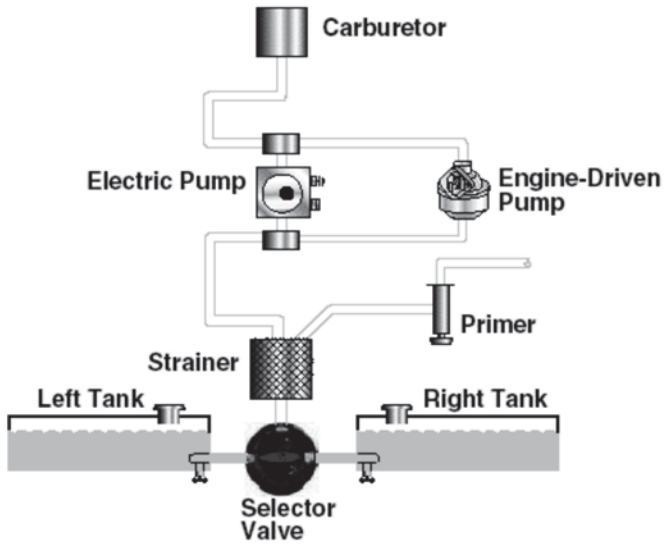

Figure A-1 Pressure-Feed System

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 24, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

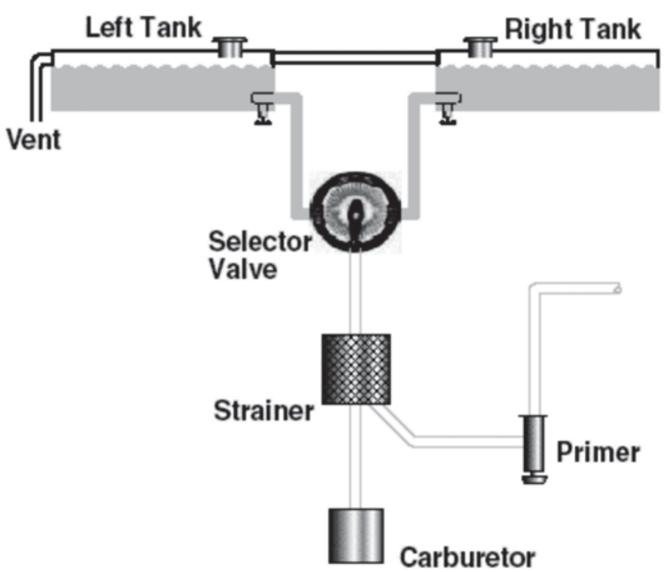

Figure A-2 Gravity-Feed System

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 24, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

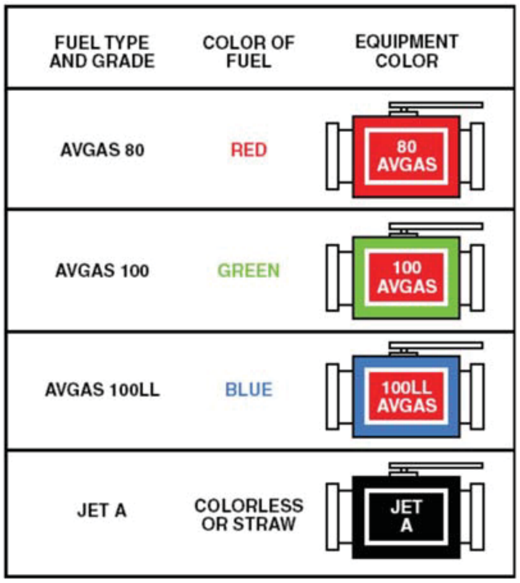

Figure A-3 Fuel Types

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 24, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

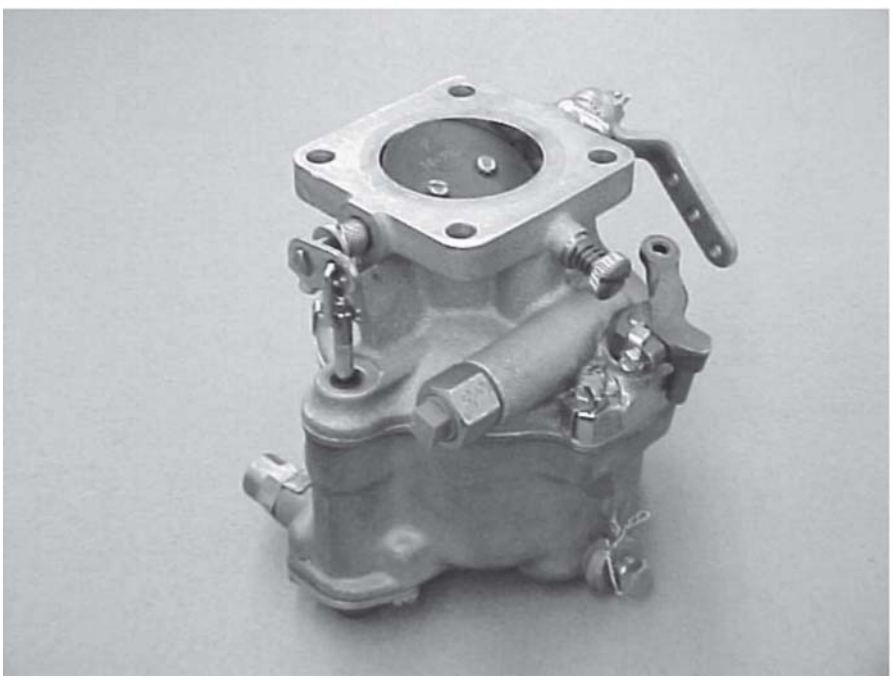

Figure A-4 Carburetor

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 24, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

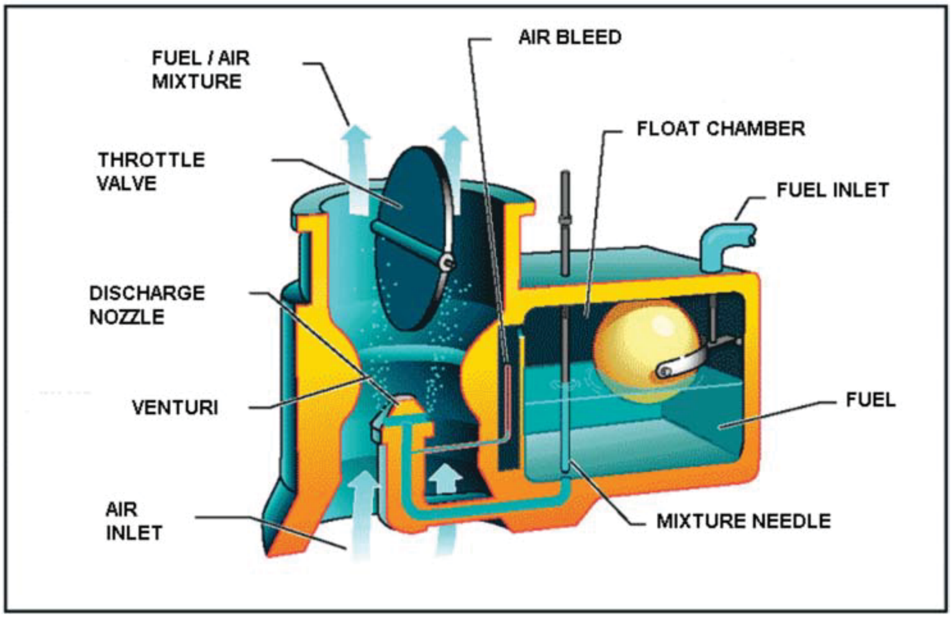

Figure A-5 Float-Type Carburetor

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 26, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

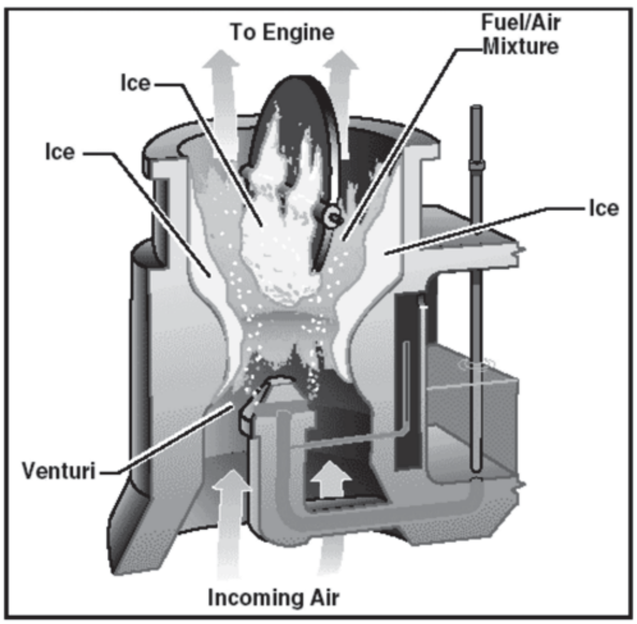

Figure A-6 Carburetor Icing

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 26, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

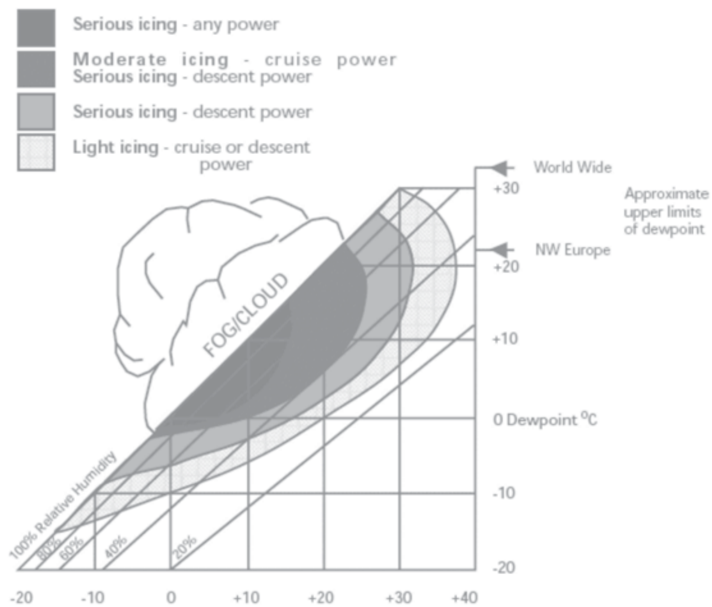

Figure A-7 Carburetor Icing Chart

Note. From "VAF Vansairforce.net", *The Truth about Carb Icing*, by J. Oldenkamp, 2006, Soonabe, Fl. Retrieved November 27, 2008, from *http*://www.vansairforce.com/community/showthread.php?t=9499

CARBURETOR STUDY HANDOUT

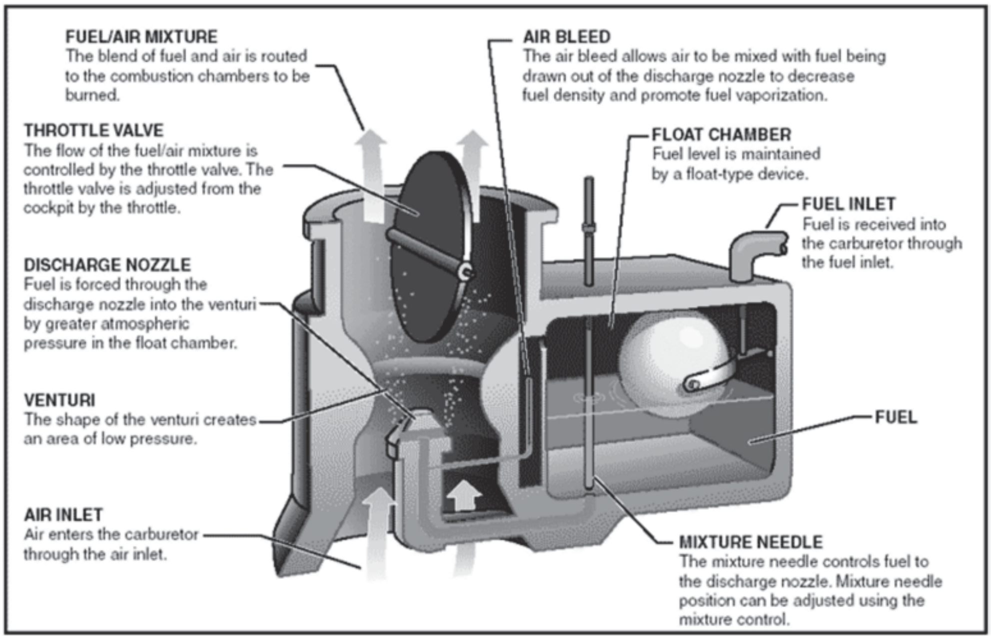

Figure B-1 Float-type Carburetor

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 26, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

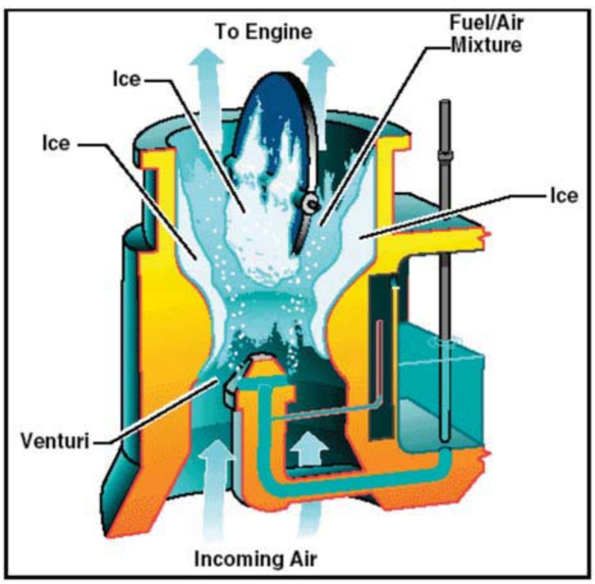

Figure B-2 Carburetor Icing

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 26, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 2

EO M432.02 – DESCRIBE PROPELLER SYSTEMS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize propeller systems.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described propeller systems.

IMPORTANCE

It is important for cadets to be able to describe propeller systems as a solid understanding of propeller systems provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1 | **Describe propeller systems.**

Time: 10 min | Method: Interactive Lecture

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

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

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

Show slide of Figure A-1 to the cadets.

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

Show slide of Figure A-2 to the cadets.

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

Show slide of Figure A-3 to the cadets.

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

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

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What does the propeller provide?

Q2. What is propeller torque?

Q3. For what is a fine pitch propeller good?

ANTICIPATED ANSWERS:

A1. The propeller provides the necessary thrust to pull, or in some cases push, the airplane through the air.

A2. It is the resistance to the blades as they rotate, resulting in a tendency in the aircraft to roll in a direction opposite to the rotation of the propeller.

A3. A fine pitch propeller will be good for taking off and climbing.

Teaching Point 2	**Describe types of propellers.**
Time: 10 min	Method: Interactive Lecture

FIXED PITCH PROPELLERS

Fixed pitch propeller. The blade angle can not be adjusted by the pilot and is used on most training aircraft. The blade angle is set by the manufacturer to provide the best compromise for all flight conditions.

VARIABLE PITCH PROPELLERS

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

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

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

The mechanism for adjusting the pitch of the propeller includes:

- mechanical,
- hydraulic, and
- electrical.

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

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

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

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. Who sets the blade angle on fixed pitch propeller?

Q2. How can the propeller pitch be adjusted?

Q3. What happens to the propeller if oil pressure is lost on a single-engine aircraft?

ANTICIPATED ANSWERS:

A1. The blade angle is set by the manufacturer.

A2. The mechanism for adjusting the pitch of the propeller includes:

- mechanical,
- hydraulic, and
- electrical.

A3. If oil pressure is lost during flight, the propeller will automatically go into fine pitch position, enabling the engine to develop the most power it can and achieve the best performance under the circumstances.

Teaching Point 3 — **Describe feathering and propeller reversing.**

Time: 5 min — Method: Interactive Lecture

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

Propeller reversing is used at slow speed to assist with stopping an aircraft once on the ground. The blade angle of a controllable pitch propeller is changed to a negative value. The reverse pitch uses engine power to produce a high negative thrust at slow speed.

> A pilot of a multi-engine aircraft can decrease the radius of a turn by using propeller reversing with the inside engine.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What is feathering?

Q2. For what is propeller reversing used?

Q3. What pitch angle is used during propeller reversing?

ANTICIPATED ANSWERS:

A1. Feathering is when blades are set to the extreme coarse pitch position and stop turning.

A2. Propeller reversing is used at slow speed to assist with stopping an aircraft once on the ground.

A3. A negative pitch angle is used during propeller reversing.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is pitch?

Q2. Name two propeller types.

Q3. What type of aircraft use propeller feathering?

ANTICIPATED ANSWERS:

A1. Pitch is the distance in feet a propeller travels forward in one revolution.

A2. Fixed pitch and variable pitch.

A3. Multi-engine aircraft.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Being able to describe propeller systems is important for understanding more complex material. A solid understanding of propellers is required to pursue future aviation training.

INSTRUCTOR NOTES / REMARKS

Nil.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

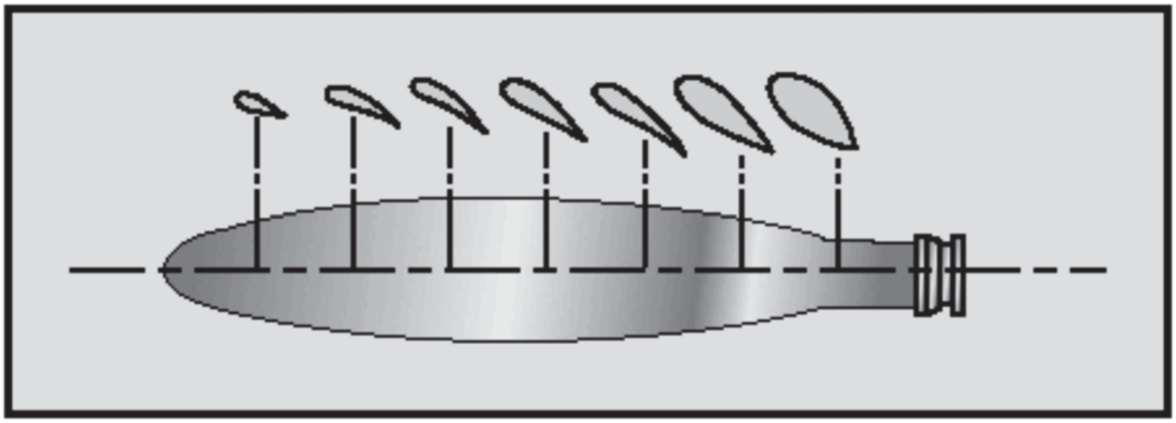


Figure A-1 Propeller Blade Shape

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 27, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

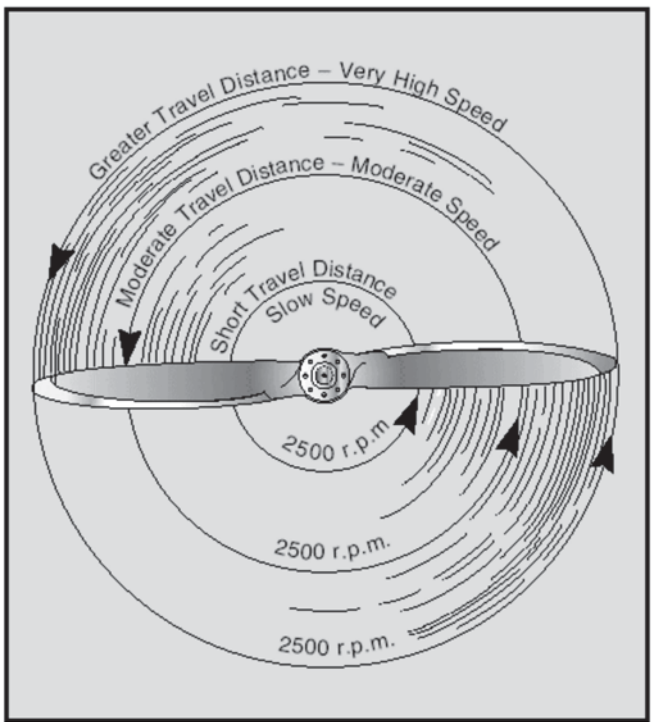


Figure A-2 Relationship of Travel Distance and Speed of Various Portions of Propeller Blade

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved November 27, 2008, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

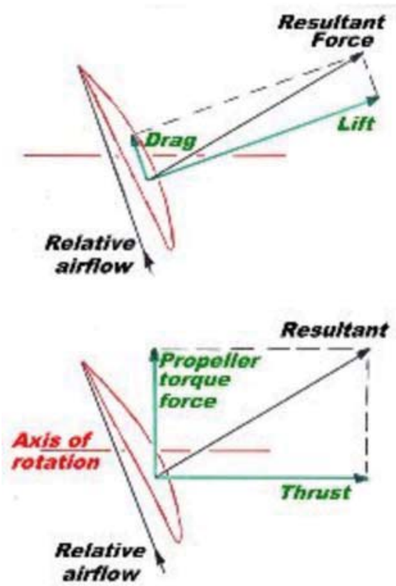


Figure A-3   Forces Acting on a Propeller Blade

Note. From "Recreational Aviation Australia Incorporated", *Engine and Propeller Performance*. Retrieved March 12, 2009, from http://www.auf.asn.au/groundschool/propeller.html

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 3

EO M432.03 – DESCRIBE ENGINE INSTRUMENTS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

Photocopy the Aero Engines Review Worksheet located at Attachment B for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1–4 to clarify, emphasize, and summarize engine instruments.

An in-class activity was chosen for TP 5 as it is an interactive way to reinforce the topic and confirm the cadets' comprehension of aero engine systems.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described engine instruments.

IMPORTANCE

It is important for cadets to be able to describe engine instruments as a solid understanding of engine instruments provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1 **Describe the oil pressure and oil temperature gauges.**

Time: 5 min Method: Interactive Lecture

Show slide of Figure A-1 to the cadets.

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. Which two gauges measure the properties of the engine oil?

Q2. When should the oil pressure gauge be first checked?

Q3. What changes in oil pressure and temperature indicates trouble?

ANTICIPATED ANSWERS:

A1. Oil pressure and temperature gauges.

A2. Immediately after the engine has been started.

A3. An abnormal drop in oil pressure and rise in oil temperature.

Teaching Point 2	**Describe the cylinder head temperature gauge.**
Time: 5 min	Method: Interactive Lecture

Show slide of Figure A-2 to the cadets.

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

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

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. Which gauge measures the effectiveness of the engine cooling system?

Q2. What do extremely high cylinder head temperatures indicate?

Q3. In what can engine overload result?

ANTICIPATED ANSWERS:

A1. The cylinder head temperature gauge.

A2. An immediate engine overload.

A3. Detonation, pre-ignition and eventual engine failure.

Teaching Point 3	**Describe the tachometer.**
Time: 5 min	Method: Interactive Lecture

Show slide of Figure A-3 to the cadets.

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

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

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

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

- green indicating normal range of operation;
- yellow indicating the caution range and possible problems; and
- red indicating the maximum limit.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What does the tachometer show?

Q2. How is the tachometer marked?

Q3. Which colours are used to indicate the proper range of engine operation?

ANTICIPATED ANSWERS:

A1. The speed at which the engine crankshaft is turning.

A2. With colour-coded arcs.

A3. Green (normal range), yellow (caution range), and red (maximum limit).

Teaching Point 4	**Describe the manifold pressure gauge.**
Time: 5 min	Method: Interactive Lecture

Show slide of Figure A-4 to the cadets.

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 4

QUESTIONS:

Q1. What does the manifold pressure gauge indicate?

Q2. What can a reduction in manifold pressure indicate?

Q3. What will the reading on the manifold pressure gauge be when the engine is not running?

ANTICIPATED ANSWERS:

A1. The gauge indicates in inches of mercury the fuel / air pressure in the engine intake manifold at the point between the carburetor and the cylinders.

A2. Carburetor icing.

A3. The existing atmospheric pressure.

Teaching Point 5	**Conduct an in-class activity to review aero engines.**
Time: 5 min	Method: In-Class Activity

OBJECTIVE

The objective of this activity is to have the cadets review aero engine systems.

RESOURCES

- Pen / pencil,
- Aero Engines Review Worksheet located at Attachment B, and
- Aero Engines Review Worksheet Answer Key located at Attachment C.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Distribute a worksheet to each cadet.
2. Have the cadets complete the worksheet.
3. When the cadets have completed their worksheet, have them review their answers using the answer key located at Attachment C.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 5

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' completion of the Aero Engines Review Worksheet will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Additional time may be required for the cadets to complete the worksheet.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Being able to describe engine instruments is important for understanding more complex material. A solid understanding of engine instruments is required to pursue future aviation training.

INSTRUCTOR NOTES / REMARKS

Nil.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

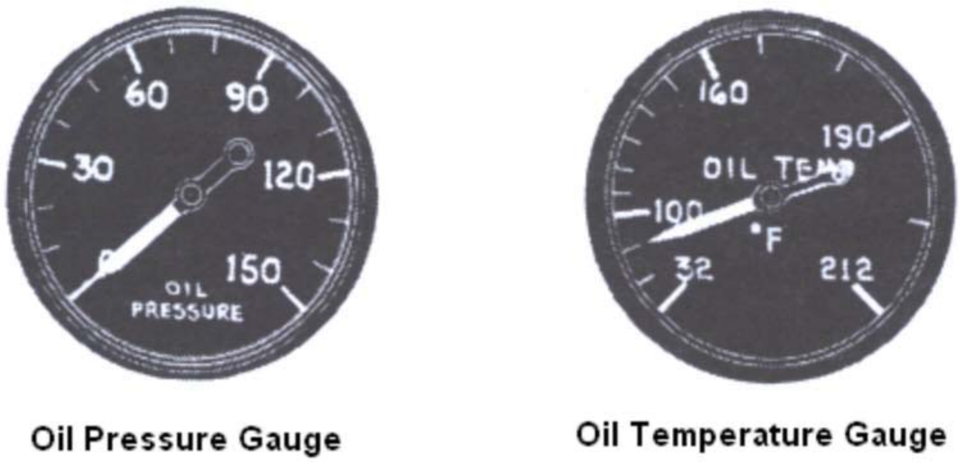


Figure A-1 Oil Pressure and Temperature Gauges

Note. From *From the Ground Up* (p. 133), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Figure A-2 Cylinder Head Temperature Gauge

Note. From *From the Ground Up* (p. 133), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

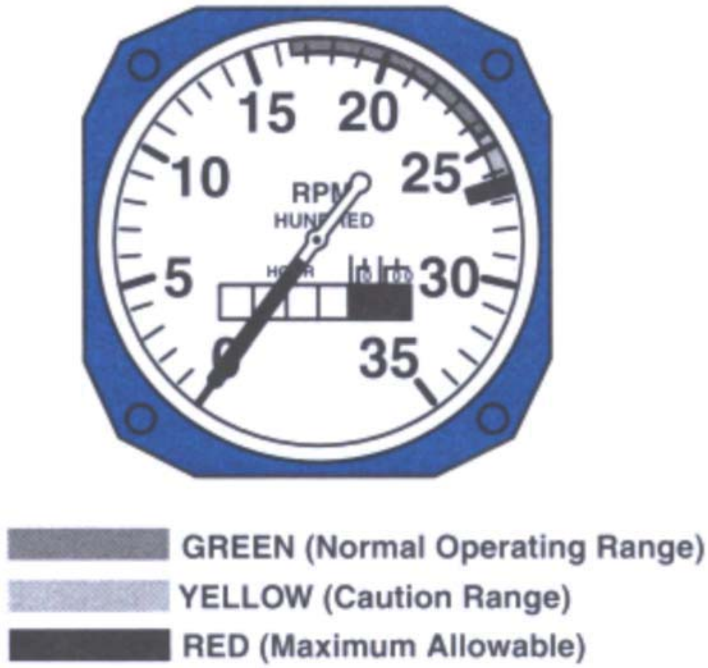


Figure A-3 Tachometer

Note. From *From the Ground Up* (p. 133), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Figure A-4 Manifold Pressure Gauge

Note. From *From the Ground Up* (p. 133), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Aero Engines Review Worksheet

1. Where should the fuel tank be positioned in a gravity feed system?

   ____.

2. What system do low-wing configured aircraft and large aircraft with a large volume of fuel use?

   ____.

3. What does the fuel selector valve, used by the pilot, do?

   ____.

4. A rich mixture is used for:

   ____.

5. How are the fuel / air proportions calculated?

   ____.

6. Which propeller would not be good for taking off and climbing?

   ____.

7. What is maintained throughout most of the diameter of the propeller by means of the variation in airfoil sections and the angle of attack?

   ____.

8. What is the distance a propeller travels forward in one revolution?

   ____.

9. What colour-coded arcs are found on the tachometer?

   ____.

10. What reading will register on the manifold pressure gauge when the engine is not running?

    ____.

11. What occurs to an engine as the altitude increases and the air becomes less?

    ____.

12. A feathered propeller is in:

    ____.

13. In what units is the oil pressure gauge calibrated?

    ____.

14. What does the tachometer show?

    ____.

15. Label the following parts on the diagram below.

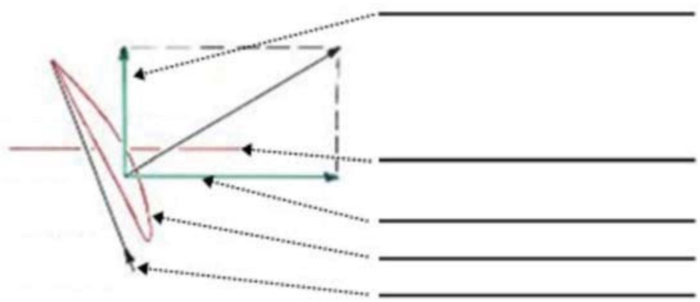
    a. Thrust

    b. Relative airflow

    c. Propeller

    d. Axis of rotation

    e. Propeller torque force



Aero Engines Review Worksheet Answer Key

1. Where should the fuel tank be positioned in a gravity feed system?

   Above the carburetor.

2. What system do low-wing configured aircraft and large aircraft with a large volume of fuel use?

   Pressure-feed system.

3. What does the fuel selector valve, used by the pilot, do?

   Select desired fuel tank to draw fuel and shut off the flow of fuel from the tanks.

4. A rich mixture is used for:

   high power settings.

5. How are the fuel / air proportions calculated?

   By volume.

6. Which propeller would not be good for taking off and climbing?

   Coarse pitch.

7. What is maintained throughout most of the diameter of the propeller by means of the variation in airfoil sections and the angle of attack?

   Thrust.

8. What is the distance a propeller travels forward in one revolution?

   Pitch.

9. What colour-coded arcs are found on the tachometer?

   Green, yellow, red.

10. What reading will register on the manifold pressure gauge when the engine is not running?

    Atmospheric pressure.

11. What occurs to an engine as the altitude increases and the air becomes less dense?

    Power decreases.

12. A feathered propeller is in:

    extreme coarse pitch position and stops turning.

13. In what units is the oil pressure gauge calibrated?

    Pounds per square inch.

14. What does the tachometer show?

    The speed at which the engine crankshaft is turning.

15. Label the following parts on the diagram below.

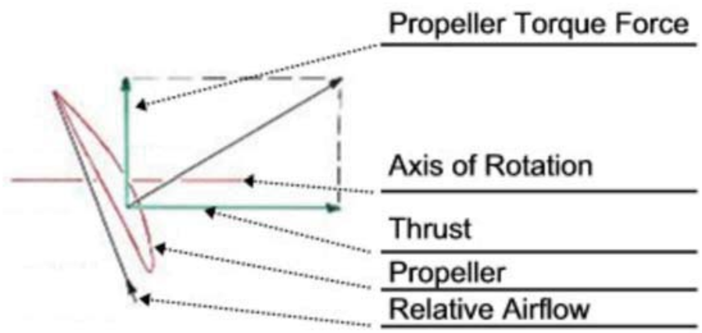
   a. Thrust

   b. Relative airflow

   c. Propeller

   d. Axis of rotation

   e. Propeller torque force



ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 4

EO C432.01 – DESCRIBE IGNITION AND ELECTRICAL SYSTEMS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize the ignition and electrical systems.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described ignition and electrical systems.

IMPORTANCE

It is important for cadets to be able to describe ignition and electrical systems as a solid understanding of ignition and electrical systems provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1	**Describe the ignition system.**
Time: 15 min	Method: Interactive Lecture

Show slide of Figure A-1 to the cadets.

The ignition system provides an electrical spark to ignite the fuel / air mixture in each cylinder. The system usually consists of:

- two magnetos,
- two spark plugs per cylinder,
- ignition leads, and
- a magneto switch (on the instrument panel).

The magneto is an engine-driven generator which produces an electrical current without using an external current. It combines all elements of the ignition system, including:

- generating a low tension current;
- transforming the low tension current to high tension; and
- distributing the current to the individual spark plugs and causing them to fire.

When the magneto switch is off, the system is grounded and the electrical charge does not flow through the magneto and a spark is not produced. When the switch is on, the system is not grounded and the electrical charge flows through the magneto and a spark can be produced.

Dual ignition systems include two spark plugs in each cylinder, and two magnetos.

One spark plug in each cylinder is fired by one magneto. The other magneto fires the second spark plug in each cylinder. This dual ignition system provides improved:

- **Safety.** If one system fails, the engine will still operate.
- **Performance.** Improved combustion of the fuel / air mixture increases the power output and gives better engine performance.

The magneto switch allows the pilot to select either one or both magneto systems. The engine should always be operated on both magneto systems during takeoff and normal flight.

The magneto switch shall be turned to off when the aircraft is parked. If the propeller is moved, the engine can fire if the ignition switch is on.

Correctly set ignition timing allows the magneto to fire at the right time. If the spark plug fires too early, poor engine performance may occur, including:

- loss of power, and
- overheating which can lead to:
  - detonation,
  - pre-ignition,
  - piston burning,
  - scored cylinders, and
  - broken rings.

The wires in the ignition system are shielded (a metal covering which is grounded). Shielding prevents the ignition current from interfering with the radio, whole ignition system, magnetos, plugs, and wiring.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What are the parts of the ignition system?

Q2. What does correct set ignition timing allow?

Q3. What does shielding prevent?

ANTICIPATED ANSWERS:

A1. The ignition system has:

- two magnetos,
- two spark plugs per cylinder,
- ignition leads, and
- a magneto switch (on the instrument panel).

A2. Allows the magneto to fire at the right time.

A3. The ignition current from interfering with the radio, whole ignition system, magnetos, plugs, and wiring.

Teaching Point 2	**Describe the electrical system.**
Time: 10 min	Method: Interactive Lecture

Show slide of Figure A-2 to the cadets.

The electrical system includes everything that operates electrically except the magnetos. There is no connection from the aircraft's electrical system to the ignition system.

The basic electrical system includes:

- a storage battery,
- master switch and battery solenoid,
- starter motor and solenoid,
- generator (or alternator),
- voltage regulator,
- bus bar, and
- circuit breakers.

The electrical system is either a 12- or 24-volt system and is direct current. The battery solenoid activated by the master switch completes the circuit between the electrical energy from the storage battery and the electrical system. The most important action by a pilot is to have the battery fully charged for the electrical components to function satisfactorily.

The starter switch activates the starter solenoid which allows current to enter and drive the starter motor.

The engine drives the generator or alternator for the purpose of providing current to the electrical system, and recharging the battery.

An alternator produces sufficient current to operate the various electrical components at low engine speeds.

A generator will not begin to supply current until the engine is turning at a faster speed.

The voltage regulator is used to prevent the generator or alternator from overloading the system, and the battery from becoming overcharged.

The current produced by the generator or alternator and battery is received by the bus bar which passes the current through the various circuit breakers and branches out to the various electrical circuits.

Circuit breakers or other fuses protect all electrical circuits from damage from excess voltage or current, and short-circuits. Most circuit breakers have a push button to reset. If the circuit breaker continues to fail, there may be malfunction in the component that could cause an electrical fire.

The pilot monitors the electrical system in the cockpit using:

- an ammeter,
- a voltmeter, and / or
- a warning light.

The ammeter measures in amperes the rate of flow of the electrical current being produced and when power is being used by the battery.

The voltmeter indicates the voltage in the electrical system.

The generator warning light shows when the generator is not working.

If the ammeter is showing on the plus (+) side of 0 on the gauge, there is satisfactory electrical operation.

If the ammeter is showing discharge or minus (-), energy is drawing from the battery rather than from the generator / alternator.

All contacts between the battery, voltage regulator, and the alternator or generator need to be clean and secure. Battery water level should be checked regularly and an aged battery that is no longer working properly should immediately be replaced.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is the most important action by a pilot regarding the electrical system?

Q2. What instruments does the pilot monitor?

Q3. What do all the contacts between the battery, voltage regulator, and the alternator or generator need to be?

ANTICIPATED ANSWERS:

A1. Ensure the battery is fully charged.

A2. An ammeter, a voltmeter, and / or a warning light.

A3. To be clean and secure.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is the difference between an alternator and a generator?

Q2. What shall the magneto switch be turned to when the aircraft is parked?

Q3. What is included in the basic electrical system?

ANTICIPATED ANSWERS:

A1. An alternator produces sufficient current to operate the various electrical components at low engine speeds while a generator will not begin to supply current until the engine is turning at a faster speed.

A2. The magneto switch shall be turned to off when the aircraft is parked.

A3. The basic system includes:

- a storage battery,
- master switch and battery solenoid,
- starter motor and solenoid,
- generator (or alternator),
- voltage regulator,

- bus bar, and
- circuit breakers.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Being able to describe ignition and electrical systems is important for understanding more complex material. A solid understanding of ignition and electrical systems is required to pursue future aviation training.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

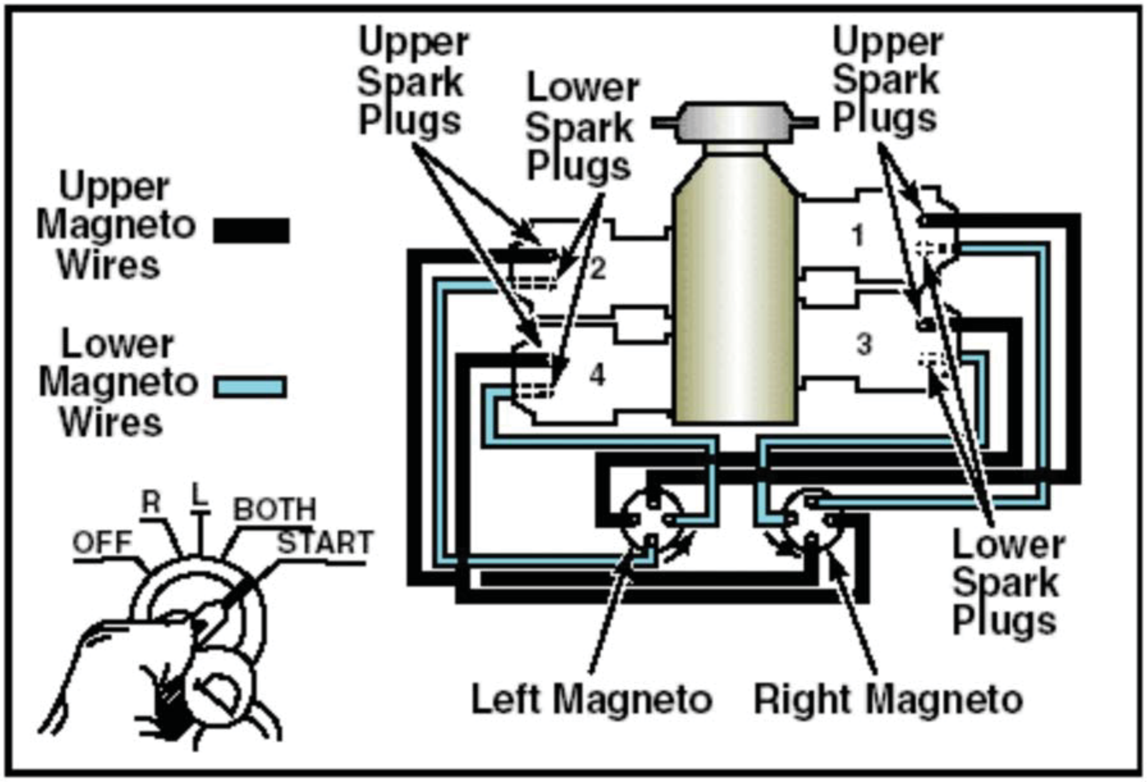


Figure A-1 Ignition System

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved March 13, 2009, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

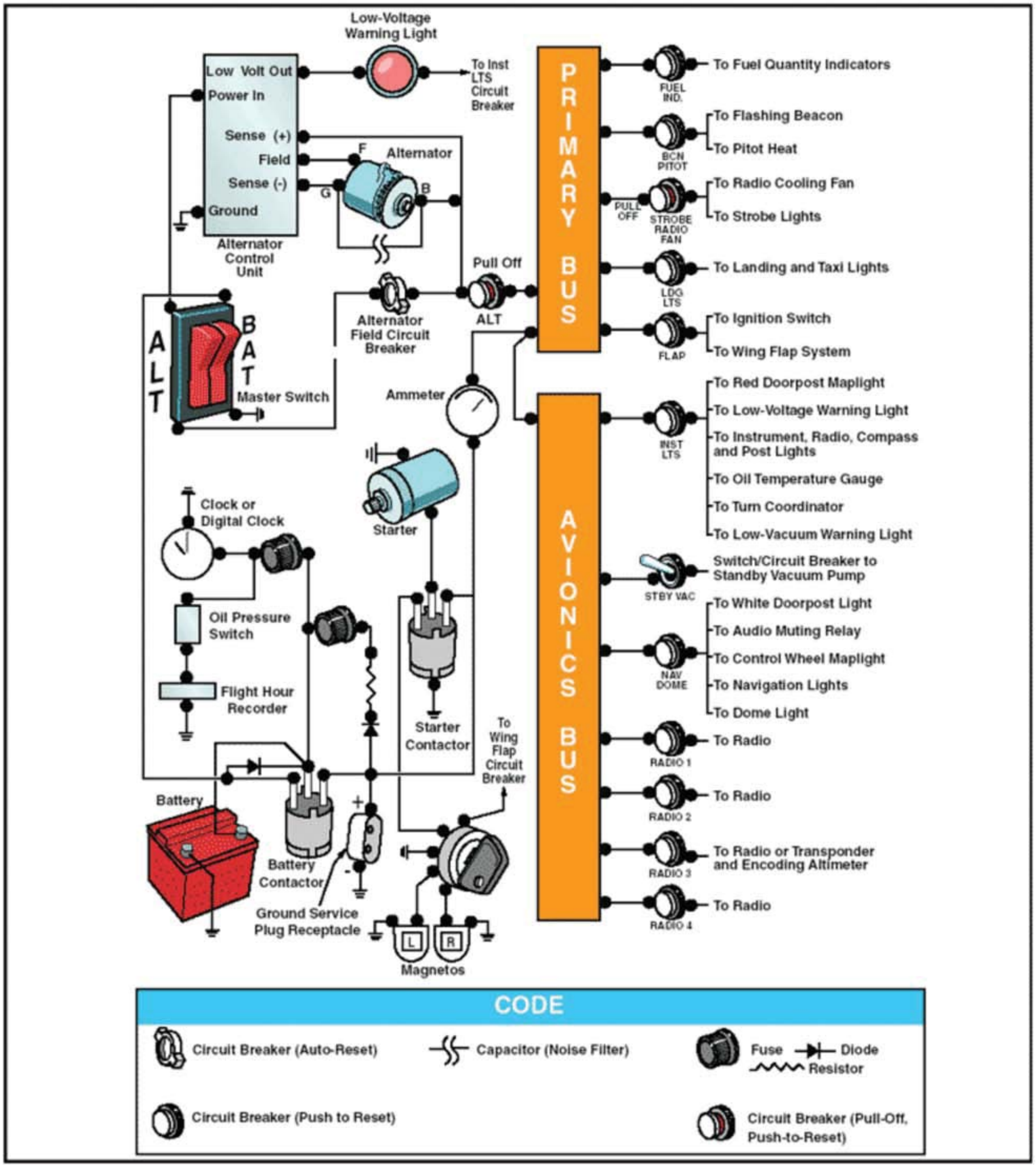


Figure A-2 Electrical System

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved March 13, 2009, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 5

EO C432.02 – DESCRIBE TURBOCHARGING AND SUPERCHARGING SYSTEMS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

Photocopy the Turbocharging and Supercharging Worksheet located at Attachment B for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to clarify, emphasize, and summarize turbocharging and supercharging systems.

An in-class activity was chosen for TP 3 to confirm the cadets' comprehension of turbocharging and supercharging.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described turbocharging and supercharging systems.

IMPORTANCE

It is important for cadets to be able to describe turbocharging and supercharging systems as a solid understanding of turbocharging and supercharging systems provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1 | **Describe turbocharging.**

Time: 10 min | Method: Interactive Lecture

Show slide of Figure A-1 to the cadets.

The capability of the engine to produce power decreases as altitude increases and the air becomes less dense. A turbocharger supplies dense air when the aircraft is operating in thin air at a high altitude using the engine power without using engine horsepower.

Show slide of Figure A-2 to the cadets.

Hot exhaust gases are discharged as waste energy and directed through a turbine wheel (impeller) at high rpm. The turbine wheel is mounted on a shaft paired with a centrifugal air compressor enclosed in separate housings. The compressor turns at the same speed as the turbine wheel. The air supplied by the compressor will be denser which enables the engine to produce more power.

The turbocharger is located between the air intake and the carburetor so the air is compressed before mixing with the fuel from the carburetor. The speed of the turbine depends on the difference in pressure between the exhaust gas and the outside pressure. The greater the difference, the less back pressure on the escaping gases and more speed by the turbine.

When flying at lower, denser altitudes, a waste gate in the exhaust system can remain open and the exhaust gas vents around the turbine into the atmosphere. Control of the turbocharger is provided by manual control, and automatic control.

Manual control. The simplest control system. It involves bleeding exhaust gas continuously through an opening of predetermined size allowing the remainder of the exhaust gas to turn the turbocharger. Engine power is adjusted by the throttle.

The more common manual control connects the throttle and the waste gate with the cockpit throttle control. A programmed movement of the throttle plate in the carburetor and the waste gate pair the opening and closing of the two systems. As the throttle plate moves toward full open, the waste gate closes.

Automatic control. A pressure controller senses the difference in air pressure and controls the position of the waste gate using pressurized oil.

The turbocharging system increases performance at altitude. It delivers full power at altitudes above the service ceiling of a normal engine.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What does a turbocharger supply?

Q2. On what does the speed of the turbine depend?

Q3. What does the pressure controller in an automatic control do when it senses a difference in air pressure?

ANTICIPATED ANSWERS:

A1. Dense air when the aircraft is operating in thin air at a high altitude.

A2. The difference in pressure between the exhaust gas and the outside pressure.

A3. It controls the position of the waste gate using pressurized oil.

Teaching Point 2	**Describe supercharging systems.**
Time: 5 min	Method: Interactive Lecture

Show slide of Figure A-3 to the cadets.

Supercharging works on the same general principles as turbocharging (eg, density). The supercharger is an internally driven compressor powered by the engine. A supercharger compresses the fuel / air mixture after it leaves the carburetor (forced induction). When forced induction is used to increase the power of an engine at low altitudes, it is called boost.

When forced induction is used at high altitude to adjust for the lower density of the air and maintain sea level power, it is called supercharging.

Turbocharging. Compressing the intake air using a turbine turned by the exhaust gases.

Supercharging. Compressing the intake air using a turbine turned by the engine / crankshaft power.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What powers the supercharger?

Q2. What is the name given when the supercharger compresses the fuel / air mixture after it leaves the carburetor?

Q3. What is supercharging?

ANTICIPATED ANSWERS:

A1. The engine powers the supercharger.

A2. Forced induction.

A3. Supercharging is the use of forced induction at high altitude to adjust for the lower density of the air and maintain sea level power.

Teaching Point 3 — **Conduct an in-class activity to confirm the cadets' comprehension of turbocharging and supercharging.**

Time: 10 min — Method: In-Class Activity

OBJECTIVE

The objective of this activity is to have the cadets confirm their comprehension of turbocharging and supercharging.

RESOURCES

- Pen / pencil,
- Turbocharging and Supercharging Worksheet located at Attachment B, and
- Turbocharging and Supercharging Worksheet Answer Key located at Attachment C.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Distribute a worksheet to each cadet.
2. Have the cadets complete the worksheet.
3. Review the answers using the answer key.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' completion of the Turbocharging and Supercharging Worksheet will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Being able to describe turbocharging and supercharging systems is important for understanding more complex material. A solid understanding of turbocharging and supercharging systems is required to pursue future aviation training.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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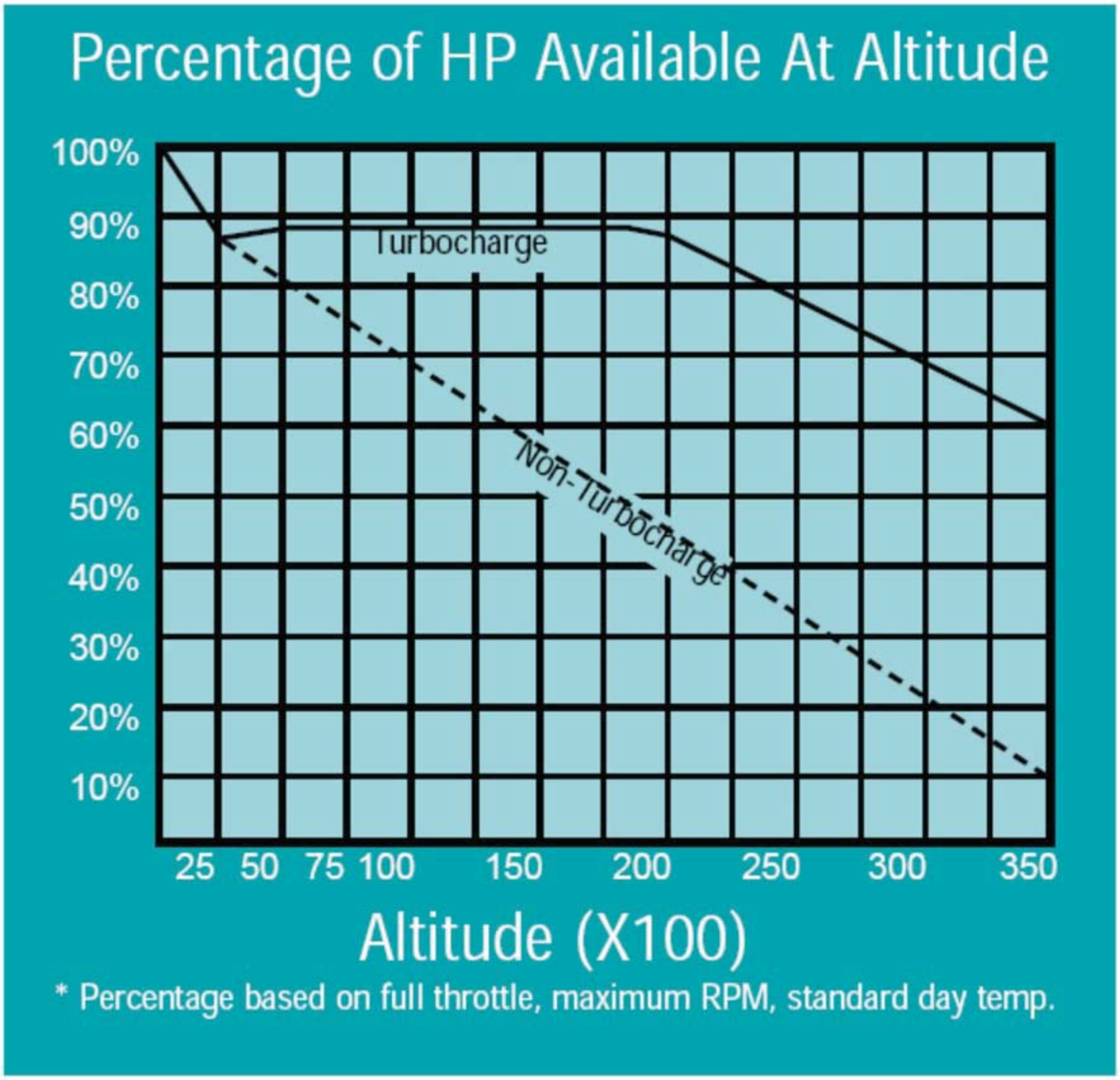


Figure A-1 Percentage of Horsepower Available at Altitude

Note. From "Boosting Your Knowledge of Tubocharging", *Kelly Aerospace*. Retrieved March 17, 2009, from http://www.kellyaerospace.com/articles/Turbocharging.pdf

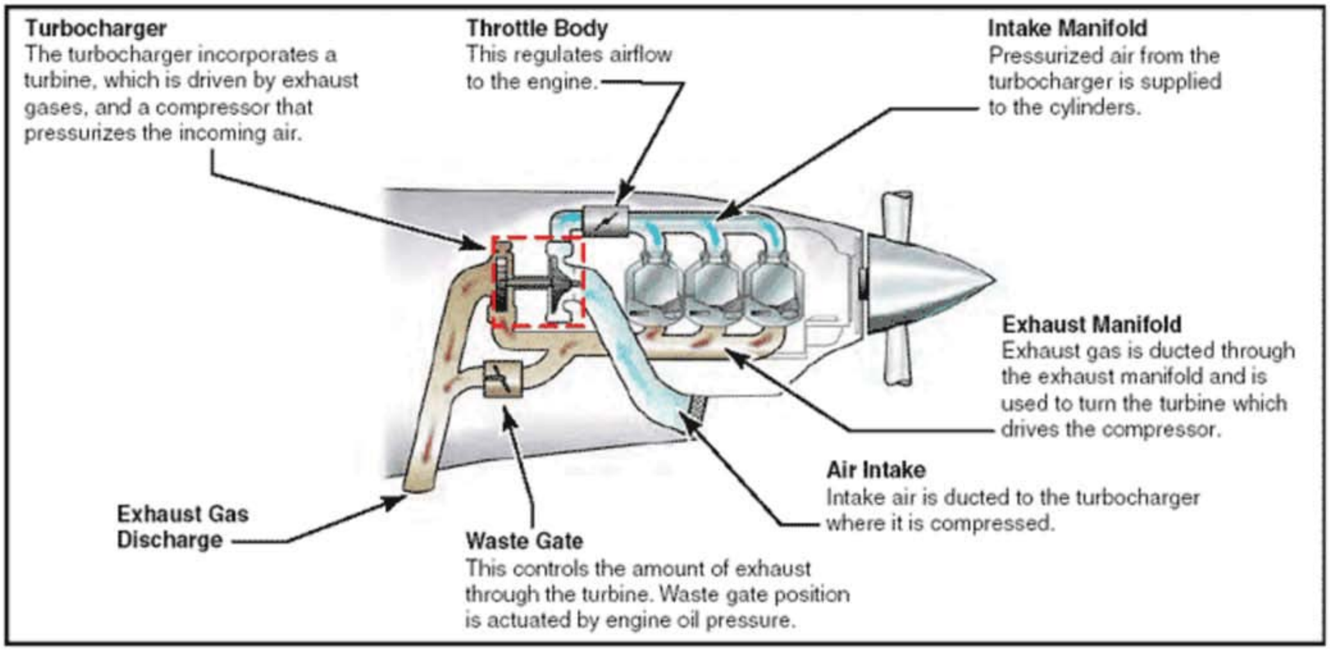
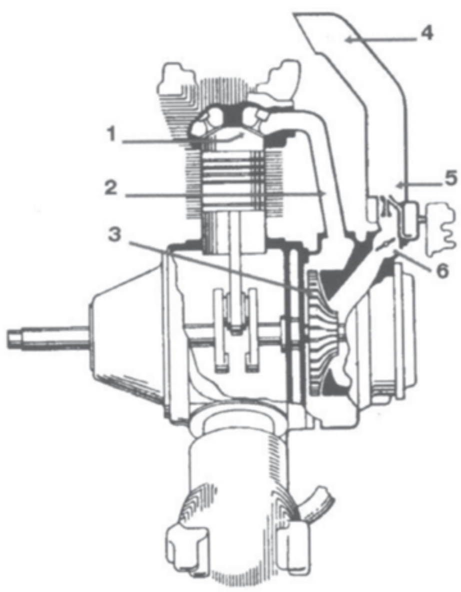


Figure A-2 Turbocharger Components

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved March 17, 2009, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html



1. intake valve
2. intake manifold
3. supercharger
4. airscoop
5. carburetor
6. throttle

Figure A-3 Supercharger Components

Note. From *From the Ground Up: Millennium Edition* (p. 56), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Turbocharging and Supercharging Worksheet

1. Place the following labels in the correct location:

   a. exhaust manifold,

   b. air intake,

   c. waste gate,

   d. exhaust gas discharge,

   e. turbocharger,

   f. throttle body, and

   g. intake manifold.

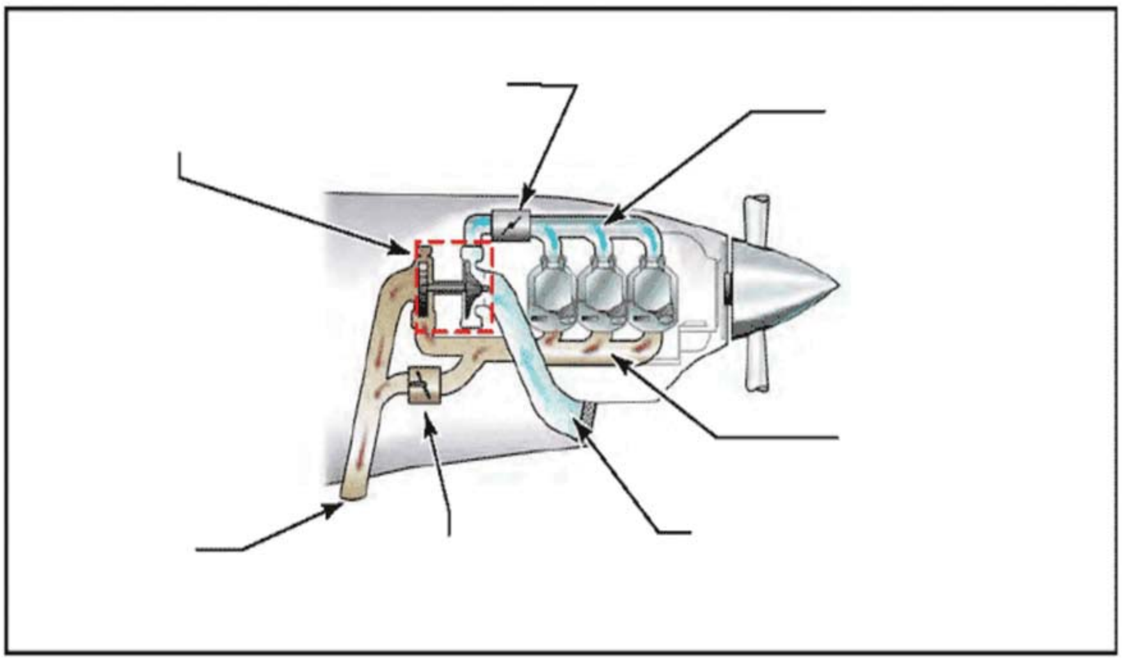


Figure B-1 Turbocharger Components

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved March 17, 2009, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

2. Explain the key differences between turbocharging and supercharging.

___

___

___

3. Place the following labels in the correct location:

   a. supercharger,

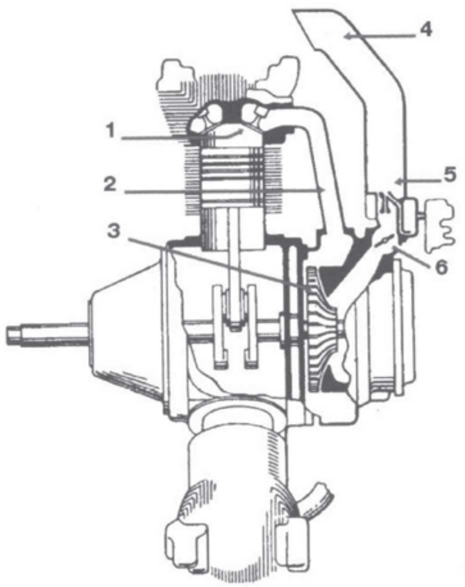
   b. intake manifold,

   c. airscoop,

   d. intake valve,

   e. carburetor, and

   f. throttle.



1. ______________________

2. ______________________

3. ______________________

4. ______________________

5. ______________________

6. ______________________

Figure B-2 Supercharger Components

Note. From *From the Ground Up: Millennium Edition* (p. 56), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Turbocharging and Supercharging Worksheet Answer Key

1. Place the following labels in the correct location:

   a. exhaust manifold,

   b. air intake,

   c. waste gate,

   d. exhaust gas discharge,

   e. turbocharger,

   f. throttle body, and

   g. intake manifold.

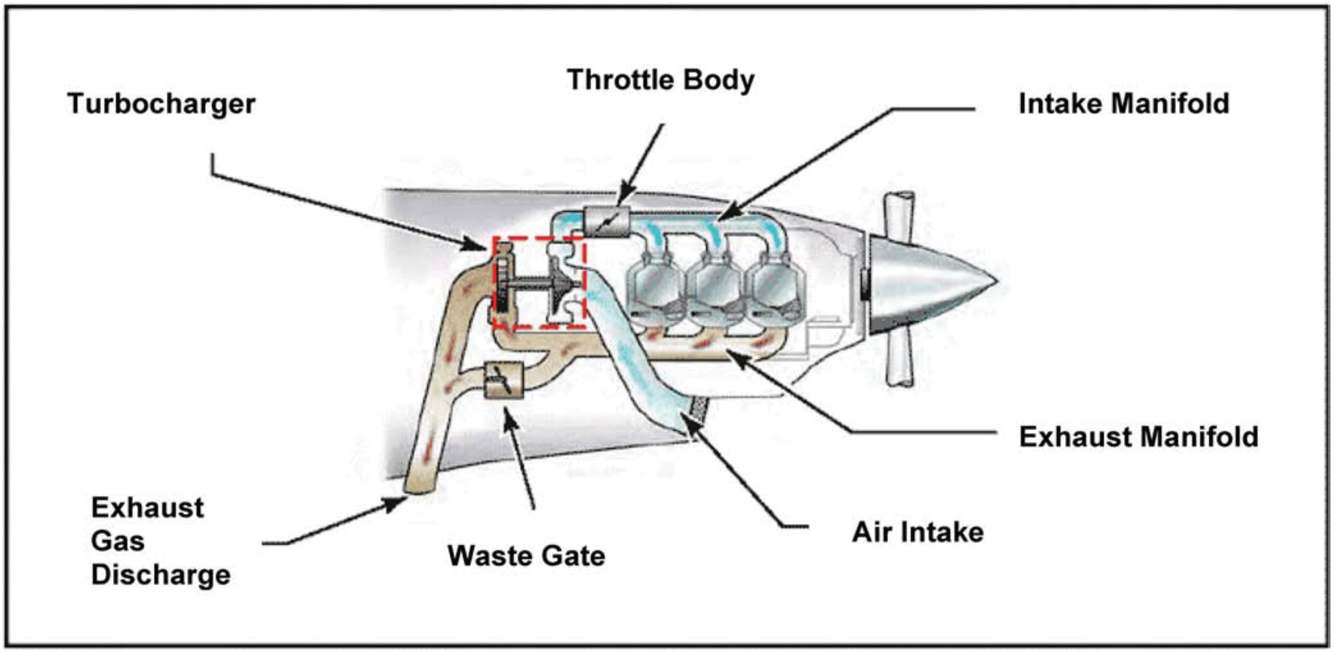


Figure C-1 Turbocharger Components

Note. From "Online Free Private Pilot Ground School", *The Aircraft Powerplant*. Retrieved March 17, 2009, from http://www.free-online-private-pilot-ground-school.com/aircraft-powerplant.html

2. Explain the key differences between turbocharging and supercharging.

A turbocharger compresses the intake air using a turbine turned by the exhaust gases.

A supercharger compresses the intake air using a turbine turned by the engine / crankshaft power.

3. Place the following labels in the correct location:

   a. supercharger,

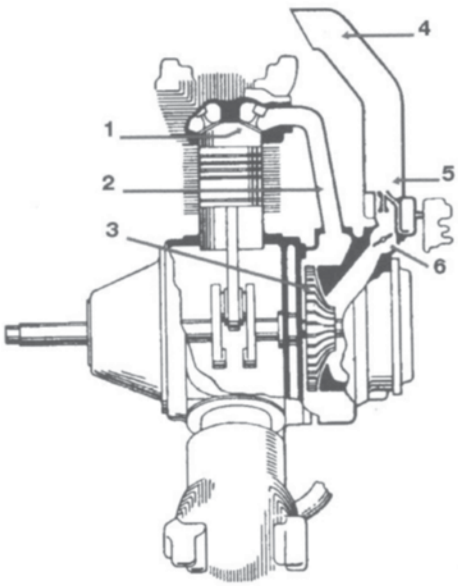
   b. intake manifold,

   c. airscoop,

   d. intake valve,

   e. carburetor, and

   f. throttle.



1. **intake valve**
2. **intake manifold**
3. **supercharger**
4. **airscoop**
5. **carburetor**
6. **throttle**

Figure C-2 Supercharger Components

Note. From *From the Ground Up: Millennium Edition* (p. 56), by A. F. MacDonald and I. L. Pepper, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 6

EO C432.03 – DESCRIBE GAS TURBINE ENGINES

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize gas turbine engines.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have described gas turbine engines.

IMPORTANCE

It is important for cadets to be able to describe gas turbine engines as a solid understanding of gas turbine engines provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

Teaching Point 1	**Describe turbojets.**
Time: 10 min	Method: Interactive Lecture

TURBOJETS

Newton’s third law states that for every action there is an equal and opposite reaction. All propulsion systems rely on this fact in some way. A turbojet engine is a reactive engine, which creates thrust by ejecting hot gases to create a force, as described by Newton’s third law of motion.

The amount of thrust developed by ejecting hot gases depends on the mass and velocity of the material ejected. A turbojet generates thrust by imparting a relatively large acceleration to a relatively small mass of air.

Show the slide of Figure A-1 to the cadets.

Air is brought into the engine through the intake opening at the front and compressed by a series of compressor blades. Once compressed, fuel is added and the mixture is ignited. The hot gases created by the very rapidly burning fuel / air mixture are highly pressurized. These high pressure gases exit at a high velocity out of the back of the engine. Between the combustion chamber and the exhaust nozzle, the high pressure gases are used to turn a turbine that is connected to the compressor blades.

In a reciprocating engine (eg, radial, in-line, horizontally opposed), a new combustion process occurs during each stroke / cycle.

In a turbojet engine, the combustion process is continuous from the time the engine is started until the engine is shut down.

To start the engine, pressurized air is injected into the engine from either an on-board or ground-based source. Another way is to use an alternate power source to spin the compressor blades, drawing air into the engine. Once a sufficient volume of air is flowing into the combustion chamber, fuel and an ignition source can be added. Once combustion has started and the hot exhaust gases are spinning the turbine connected to the compressor blades, the engine is capable of drawing air into itself on its own, and the on-board or ground-based air / power source can be disconnected.

As an aircraft with a turbojet engine flies faster, more air is pushed into the engine as a result of the forward motion. This improves the fuel efficiency of the engine. A turbojet engine becomes more fuel efficient as the airspeed increases.

Conversely, turbojets become fuel inefficient at low airspeeds.

Turbojets can usually be identified visually by their external shape. Turbojets typically have a constant diameter from the front of the engine (air intake) to the rear of the engine (exhaust nozzle).

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. Which law of motion does a turbojet engine demonstrate?

Q2. What is different about the combustion in a turbojet engine, when compared to a reciprocating engine?

Q3. What happens to the fuel efficiency of a turbojet engine as the airspeed increases?

ANTICIPATED ANSWERS:

A1. A turbojet engine demonstrates Newton's third law of motion.

A2. In a turbojet engine, the combustion process is continuous from the time the engine is started until the engine is shut down.

A3. A turbojet engine becomes more fuel efficient as the airspeed increases.

Teaching Point 2	**Describe turbofans.**
Time: 10 min	Method: Interactive Lecture

TURBOFANS

Show the slide of Figure A-2 to the cadets.

The turbofan is a turbojet with a fan attached in front of the compressor blades. The fan diameter is larger than the engine core and some of the air moved by the fan bypasses the engine core. This air is moved backwards by the fan in the same way that a propeller works and creates additional thrust for the engine.

In a low-bypass turbofan, the amount of air that bypasses the engine and the amount of air that enters the engine core are approximately equal. In a high-bypass turbo fan, approximately four times as much air may bypass the engine core, which may result in up to 80 percent of the total thrust coming from the bypass portion of the engine.

Show the slide of Figure A-3 to the cadets.

Turbofans are more fuel efficient than turbojets, especially at lower airspeeds. They also produce less noise than turbojets. A turbofan produces more thrust than a turbojet of a similar physical size.

Turbofans can usually be identified visually by their external shape. Turbofans typically have an air intake that is two to four times the diameter of the exhaust nozzle.

Additional advantages of a turbofan engine include:

- very high power to weight ratio, compared to reciprocating and turbojet engines; and
- less vibration than a reciprocating engine.

Disadvantages of a turbofan engine include:

- high cost, and
- delayed response to changes in power settings.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is a turbofan engine?

Q2. How much air may bypass the engine core in a high-bypass turbofan engine?

Q3. What are two advantages of a turbofan engine?

ANTICIPATED ANSWERS:

A1. A turbofan is a turbojet with a fan attached in front of the compressor blades.

A2. In a high-bypass turbofan approximately four times as much air that enters the engine core may bypass the engine core.

A3. Two advantages of a turbofan engine include:

- very high power to weight ratio, compared to reciprocating and turbojet engines; and
- less vibration than a reciprocating engine.

Teaching Point 3	**Describe turboprops and turboshafts.**
Time: 5 min	Method: Interactive Lecture

Instead of using the power of the exhaust gases to produce thrust directly, the gases can be used to turn a turbine connected to a propeller or a shaft.

TURBOPROPS

Show the slide of Figure A-4 to the cadets.

When the power of the exhaust gases are used to turn a propeller, the engine is called a turboprop. In a fixed shaft turboprop, the same turbine turns both the compressor blades and the shaft connected to the propeller. In a free turbine turboprop, a separate turbine is used to turn the shaft connected to the propeller.

The PT6 turboprop engine, manufactured by Pratt and Whitney Aircraft of Canada, is one of the most popular turboprop engines in the world. It comes in a variety of power outputs and is used in a wide range of aircraft.

In all turboprop engines, the shaft from the turbine is connected to a gearbox to reduce the speed of the shaft to a range that is suitable for spinning the propeller.

TURBOSHAFTS

If the shaft of the gas turbine engine is connected to something other than a propeller, the engine is called a turboshaft. The shaft will be connected to a transmission system, and may be used to drive helicopter rotors, electrical generators, compressors, pumps, marine propulsion systems (eg, ships), and / or land propulsion systems (eg, tanks).

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What is the difference between a turboprop and a turboshaft engine?

Q2. What is the shaft connected to in a turboprop engine to reduce the speed of the shaft?

Q3. For what can a turboshaft engine be used?

ANTICIPATED ANSWERS:

A1. In a turboprop engine, the shaft is connected to a propeller; in a turboshaft engine, it is connected to something other than a propeller.

A2. In a turboprop engine, the shaft from the turbine is connected to a gearbox to reduce the speed of the shaft to a range that is suitable for spinning the propeller.

A3. A turboshaft engine may be used for:

- helicopter rotors,
- electrical generators,
- compressors,
- pumps,
- marine propulsion systems (eg, ships), and / or
- land propulsion systems (eg, tanks).

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. How does a turbojet generate thrust?

Q2. How can a turbofan be visually identified?

Q3. How is a free turbine turboprop different from a fixed shaft turboprop?

ANTICIPATED ANSWERS:

A1. A turbojet generates thrust by imparting a relatively large acceleration to a relatively small mass of air.

A2. Turbofans typically have an air intake that is two to four times the diameter of the exhaust nozzle.

A3. In a free turbine turboprop, a separate turbine is used to turn the shaft connected to the propeller. In a fixed shaft turboprop, the same turbine turns both the compressor blades and the shaft connected to the propeller.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Being able to describe gas turbine engines is important for understanding more complex material. A solid understanding of gas turbine engines is required to pursue future aviation training and provides knowledge for potential instructional duties.

INSTRUCTOR NOTES / REMARKS

Nil.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

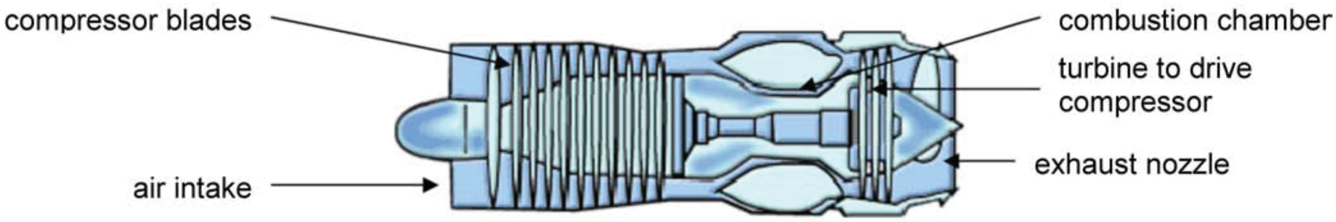


Figure A-1 Turbojet Engine

Note. From "Engines", *NASA Ultra Efficient Engine Technology*. Retrieved March 19, 2009, from http://www.ueet.nasa.gov/StudentSite/engines.html

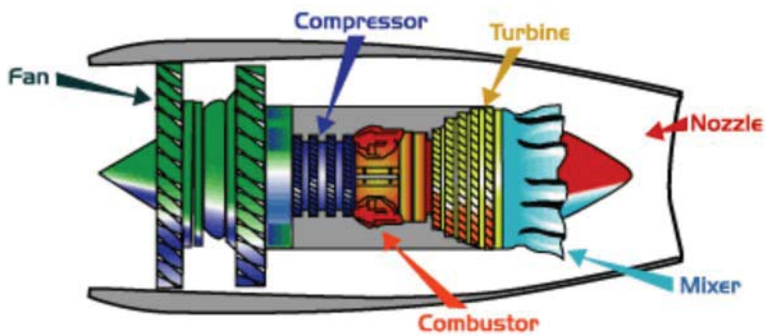


Figure A-2 Turbofan Engine

Note. From "Engines", *NASA Ultra Efficient Engine Technology*. Retrieved March 19, 2009, from http://www.ueet.nasa.gov/StudentSite/engines.html

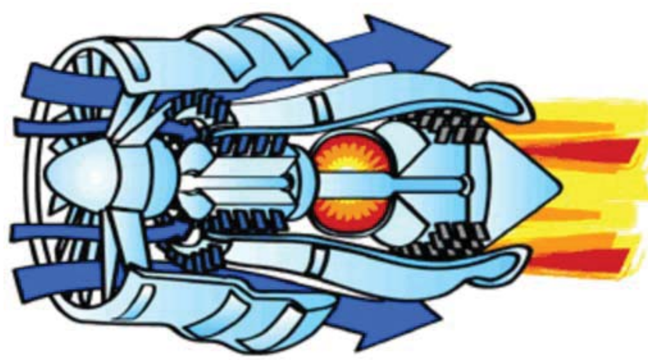


Figure A-3 Airflow Through a Turbofan Engine

Note. From "Engines", *NASA Ultra Efficient Engine Technology*. Retrieved March 19, 2009, from http://www.ueet.nasa.gov/StudentSite/engines.html

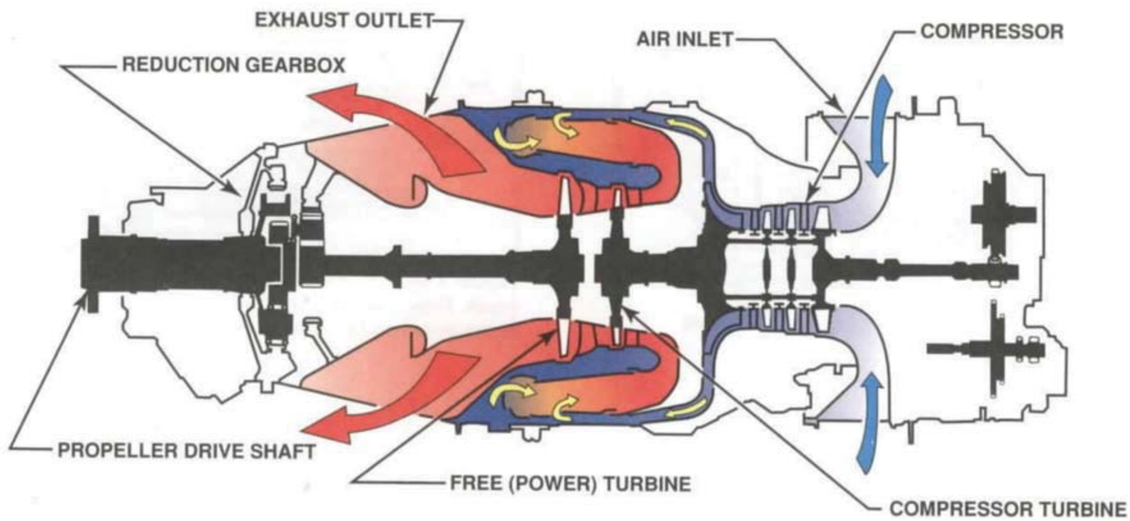


Figure A-4 Free Turbine Turboprop Engine

Note. From *A&P Technician Powerplant* (p. 3-6), by Jeppesen Standard Training Products, 2000, Englewood, CO:Jeppesen Sanderson Training Systems.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 1

EO M436.01 – EXPLAIN WINDS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare the slides or handouts located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to winds and generate interest in the subject.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have explained winds.

IMPORTANCE

It is important for the cadets to explain winds as this information is used by pilots to be aware of the direction and speed of wind during all parts of the flight. Being able to explain winds provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

Teaching Point 1	**Explain surface winds.**
Time: 15 min	Method: Interactive Lecture

SURFACE WINDS

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

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

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

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

Katabatic and Anabatic Winds

Show slides of Figures A-1 and A-2.

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

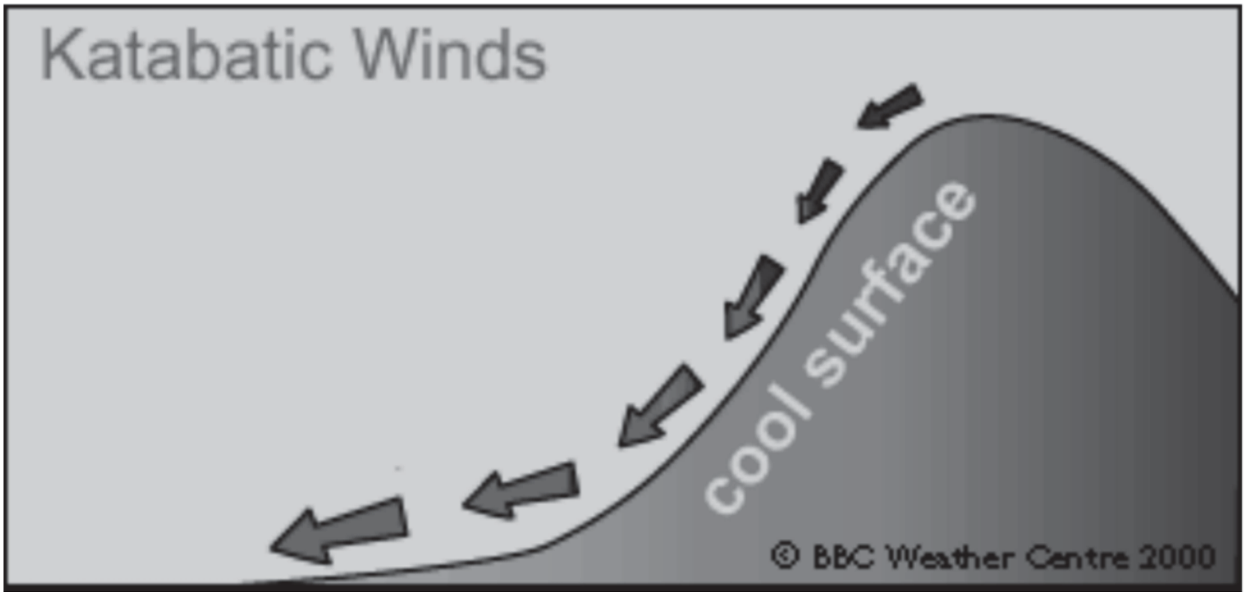


Figure 1 Katabatic Wind

Note. From "Wind", by BBC, 2008. Copyright 2000 by BBC Weather Centre. Retrieved October 14, 2008, from http://www.bbc.co.uk/weather/weatherwise/factfiles/basics/wind_localwinds.shtml

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

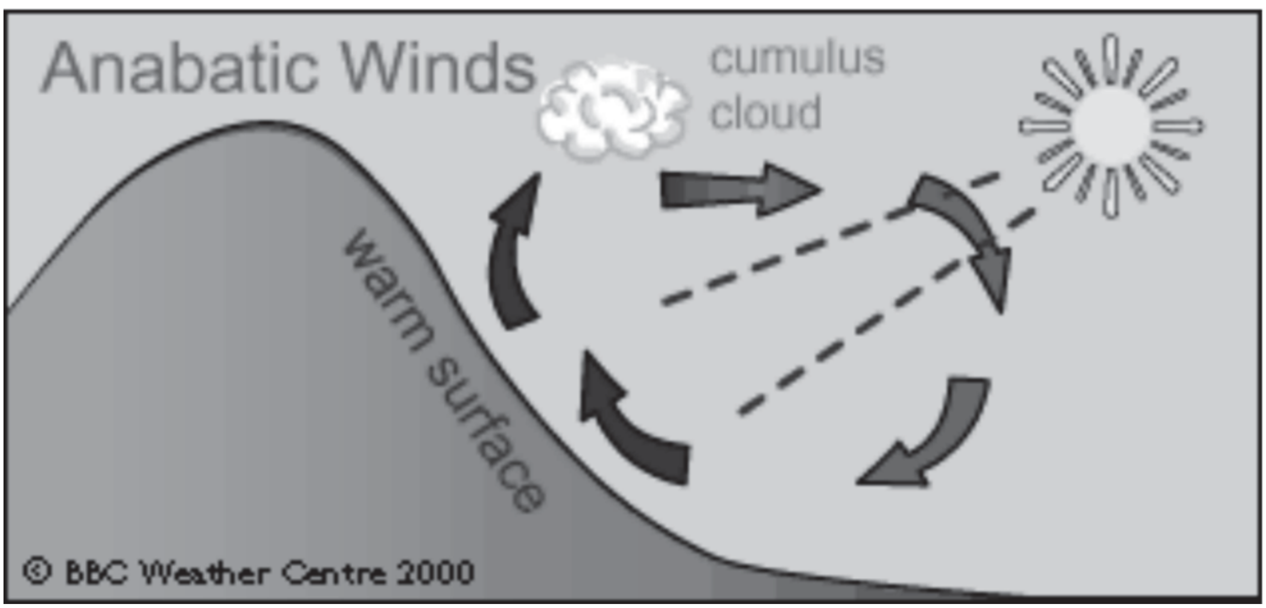


Figure 2 Anabatic Wind

Note. From "Wind", by BBC, 2008. Copyright 2000 by BBC Weather Centre. Retrieved October 14, 2008, from http://www.bbc.co.uk/weather/weatherwise/factfiles/basics/wind_localwinds.shtml

Mountain Waves

Show slide of Figure A-3.

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

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

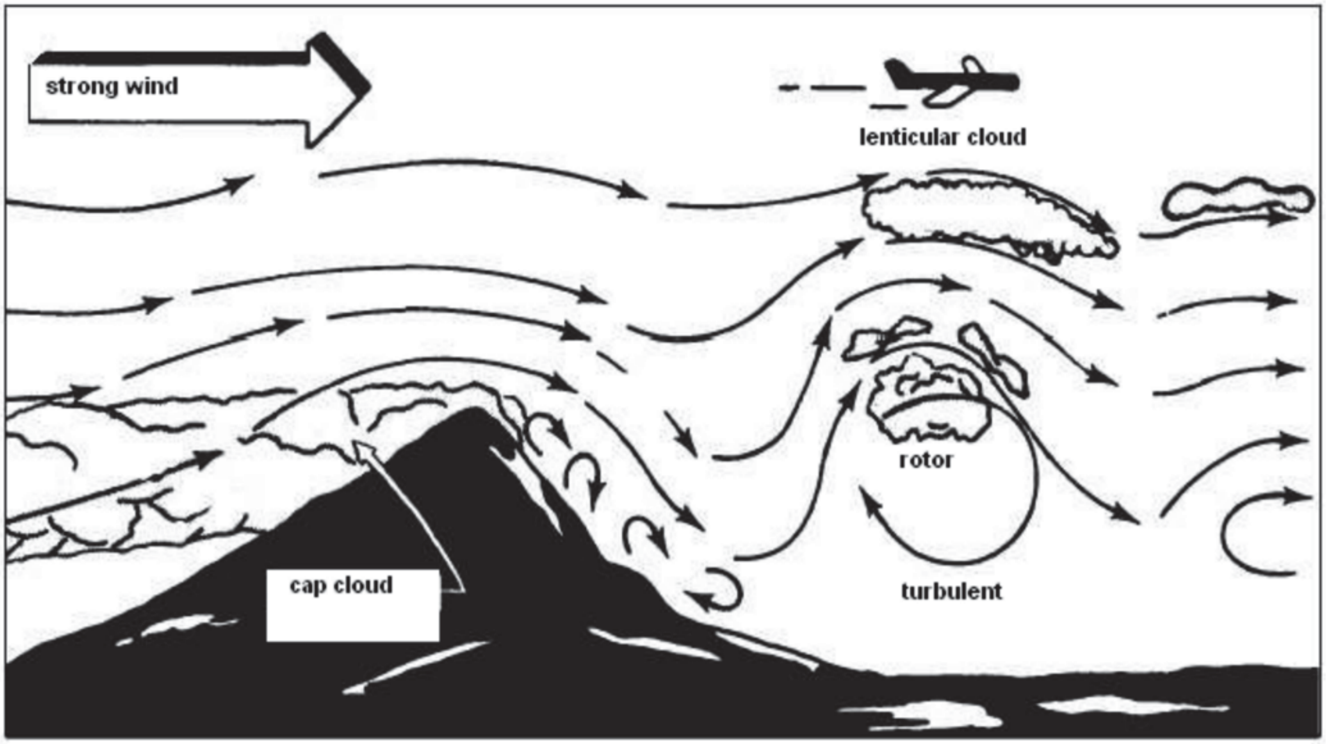


Figure 3 Mountain Wave

Note. From "Integrated Publishing", 2003. *Aerographer / Meteorology*, Copyright 2003 by Integrated Publishing. Retrieved October 14, 2008, from http://www.tpub.com/weather2/3-25.htm

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

- common downdrafts of 2 000 feet per minute along the downward slope;
- extremely severe turbulence in the air layer between the ground and the tops of the rotor clouds;
- severe wind shear due to wind speed variation between the crests and troughs of the waves;

- severe icing due to large supercooled droplets sustained in the strong vertical currents; and
- an altimeter error of more than 3 000 feet on the high side due to the increase in wind speed and accompanying decrease in pressure.

Gusts

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

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

Squalls

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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. Explain anabatic wind.

Q2. What types of clouds are caused by mountain waves?

Q3. What causes gusts?

ANTICIPATED ANSWERS:

A1. Anabatic wind occurs during the day when the slopes of hills not covered by snow are warmed. The air in contact with them becomes warmer and less dense, therefore flowing up the slope.

A2. Cap clouds, lenticular clouds, and rotor clouds.

A3. Gusts are caused by mechanical turbulence that results from friction between the air and the ground and by the unequal heating of the earth's surface.

Teaching Point 2	**Describe jet streams.**
Time: 10 min	Method: Interactive Lecture

JET STREAMS

Show slides of Figures A-4 and A-5.

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

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

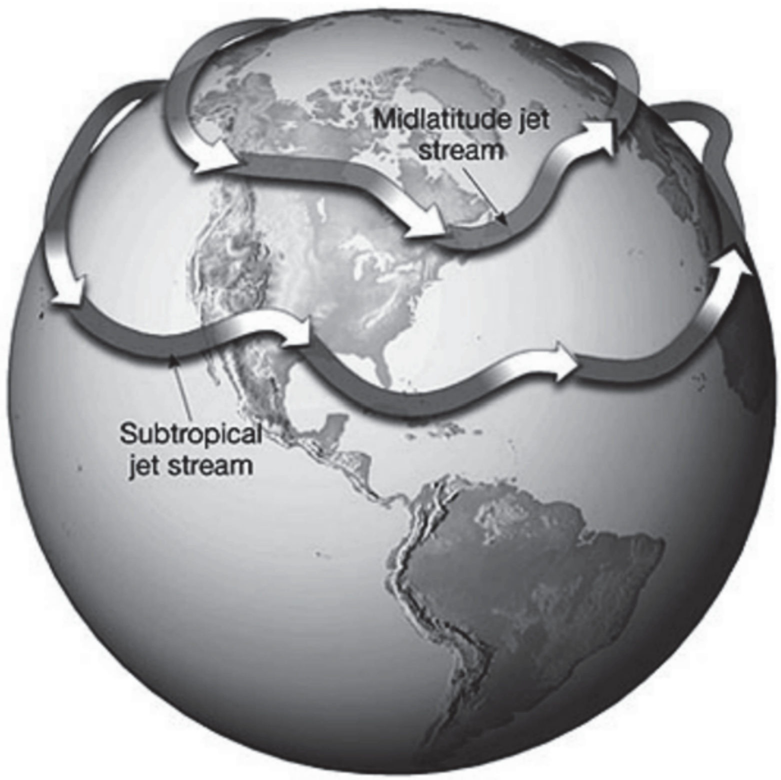


Figure 4 The Jet Stream

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

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

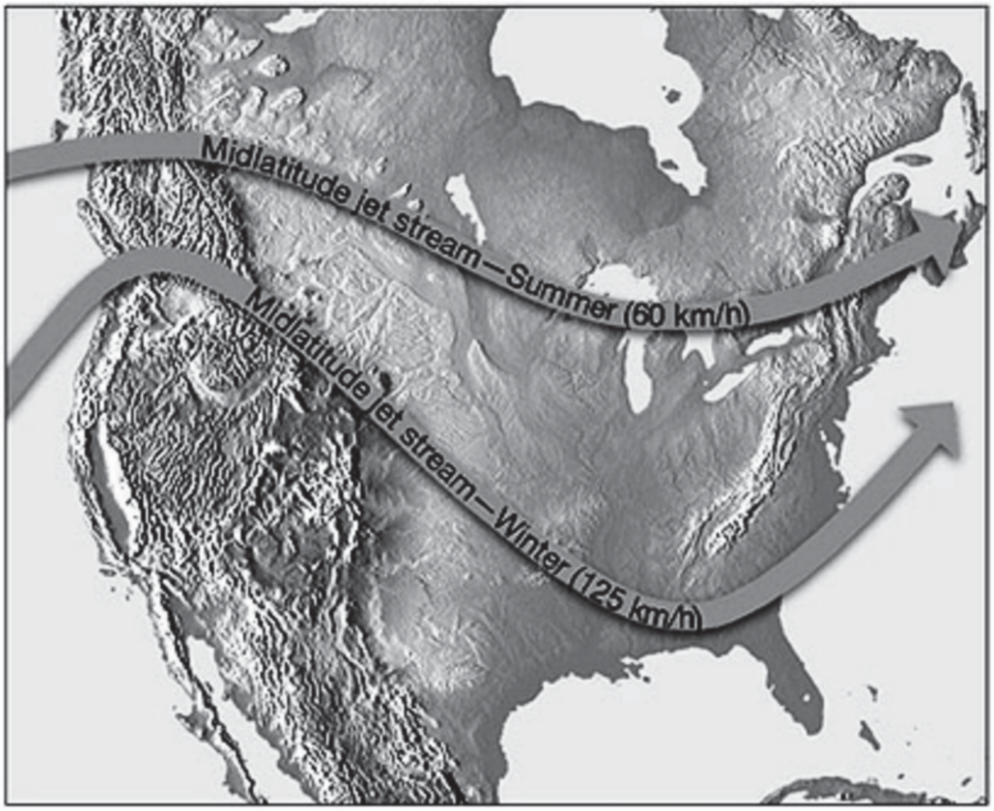


Figure 5 Seasonal Mid-Latitude Jet Stream

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

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

Clear Air Turbulence (CAT)

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

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What are jet streams?

Q2. In what direction do jet streams flow?

Q3. Where is clear air turbulence most likely to occur?

ANTICIPATED ANSWERS:

A1. Jet streams are narrow bands of exceedingly high speed winds that exist in the higher levels of the atmosphere at altitudes ranging from 20 000 to 40 000 feet or more.

A2. Jet streams flow from west to east.

A3. Clear air turbulence is most likely to occur just above the central core of a jet stream.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What must pilots be aware of when close to the ground during takeoff and landing?

Q2. List examples of wind phenomena in mountainous areas.

Q3. What is the range of wind speeds in the central core of the jet stream?

ANTICIPATED ANSWERS:

A1. The direction and speed of wind.

A2. Examples include:

- katabatic winds,
- anabatic winds, and
- mountain waves.

A3. 100 to 150 knots but may reach speeds as great as 250 knots.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Wind is a major factor in flight planning and flight characteristics. Pilots must constantly be aware of the direction and speed of wind during all parts of the flight. Knowledge of winds is essential for future aviation training and for instructional duties at the squadron.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-334 Short, N. (2005). Remote Sensing Tutorial. *Federation of American Scientists*. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

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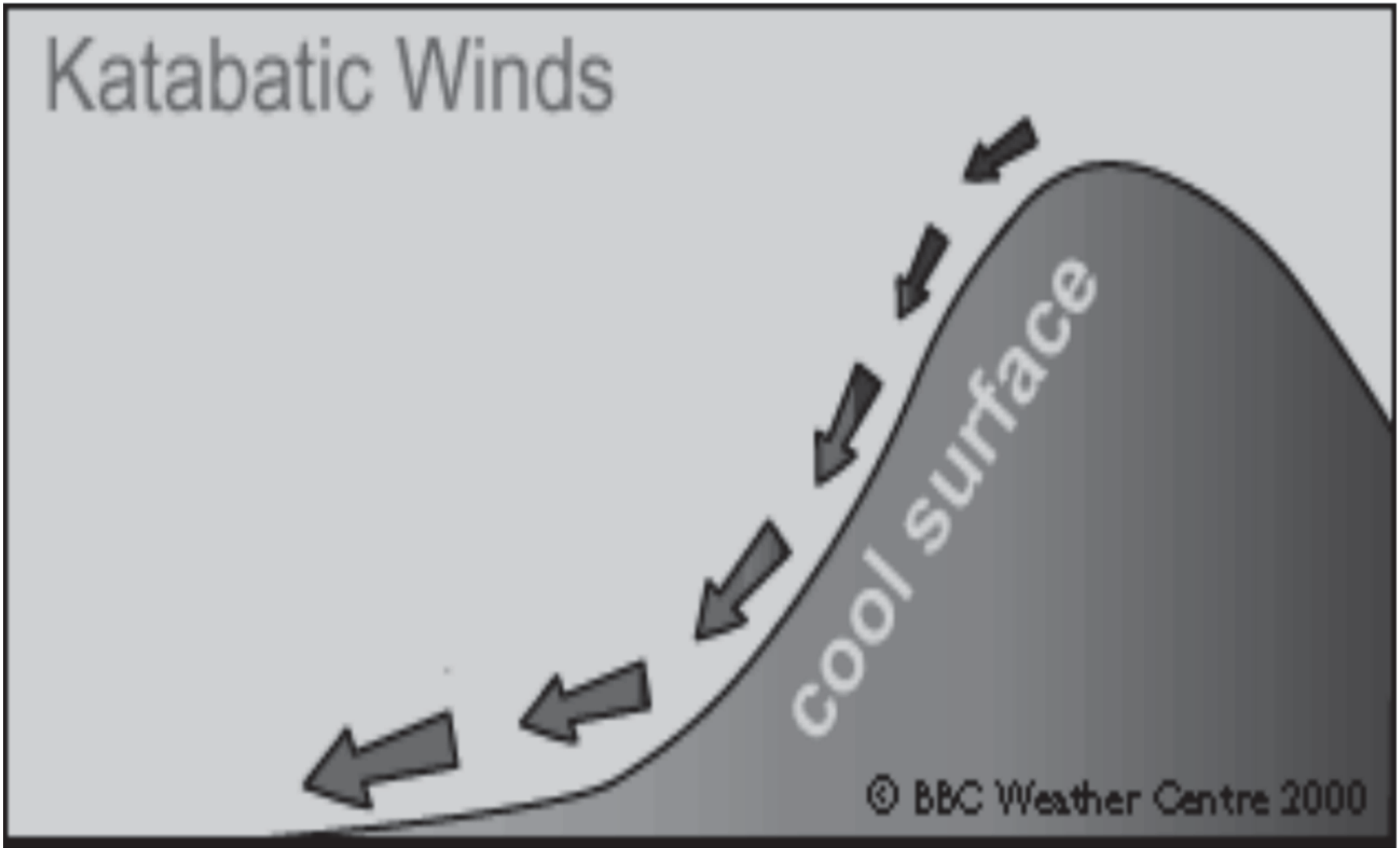

Figure A-1 Katabatic Wind

Note. From "Wind", by *BBC*, 2008. Copyright 2000 by BBC Weather Centre. Retrieved October 14, 2008, from http://www.bbc.co.uk/weather/weatherwise/factfiles/basics/wind_localwinds.shtml

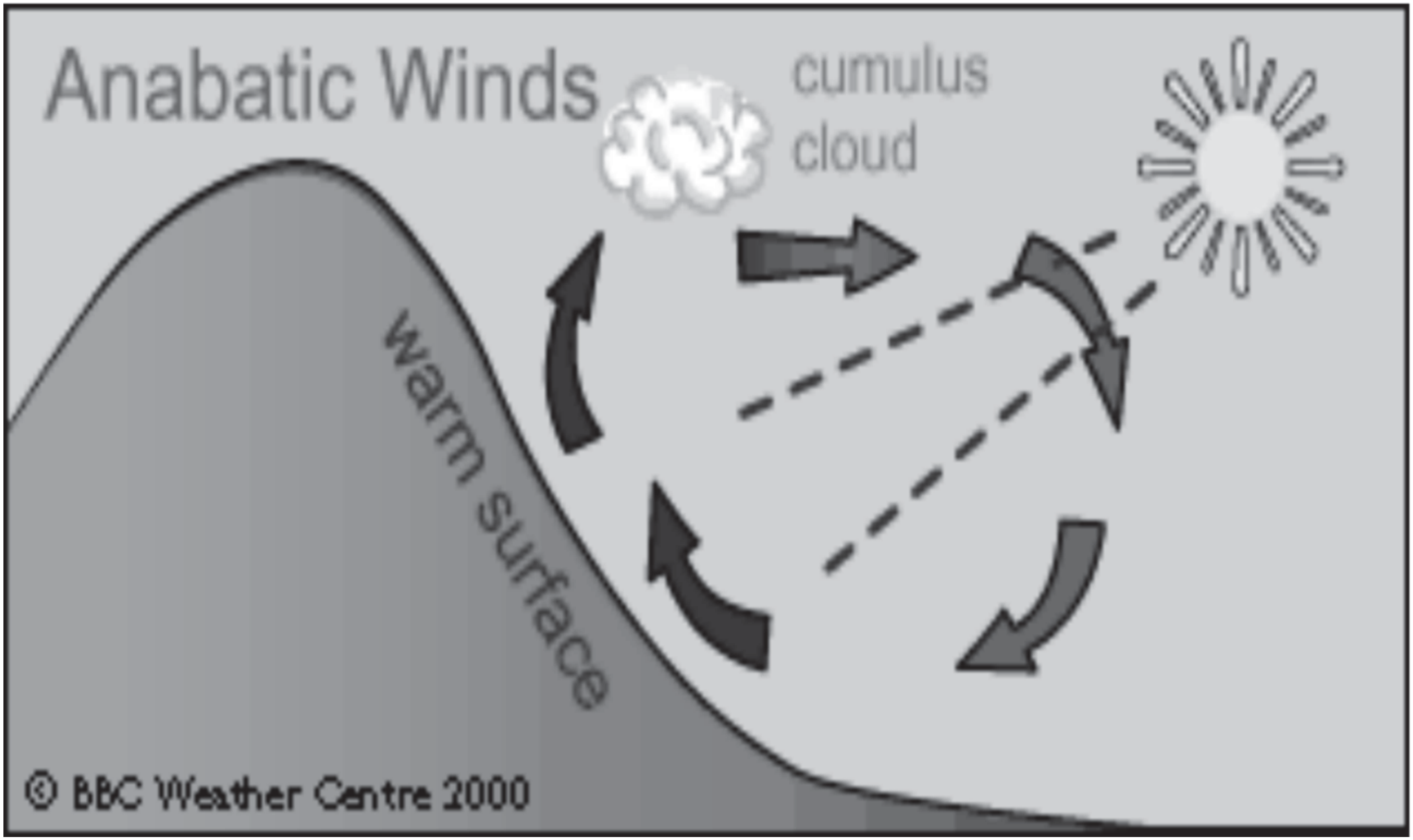

Figure A-2 Anabatic Wind

Note. From "Wind", by *BBC*, 2008. Copyright 2000 by BBC Weather Centre. Retrieved October 14, 2008, from http://www.bbc.co.uk/weather/weatherwise/factfiles/basics/wind_localwinds.shtml

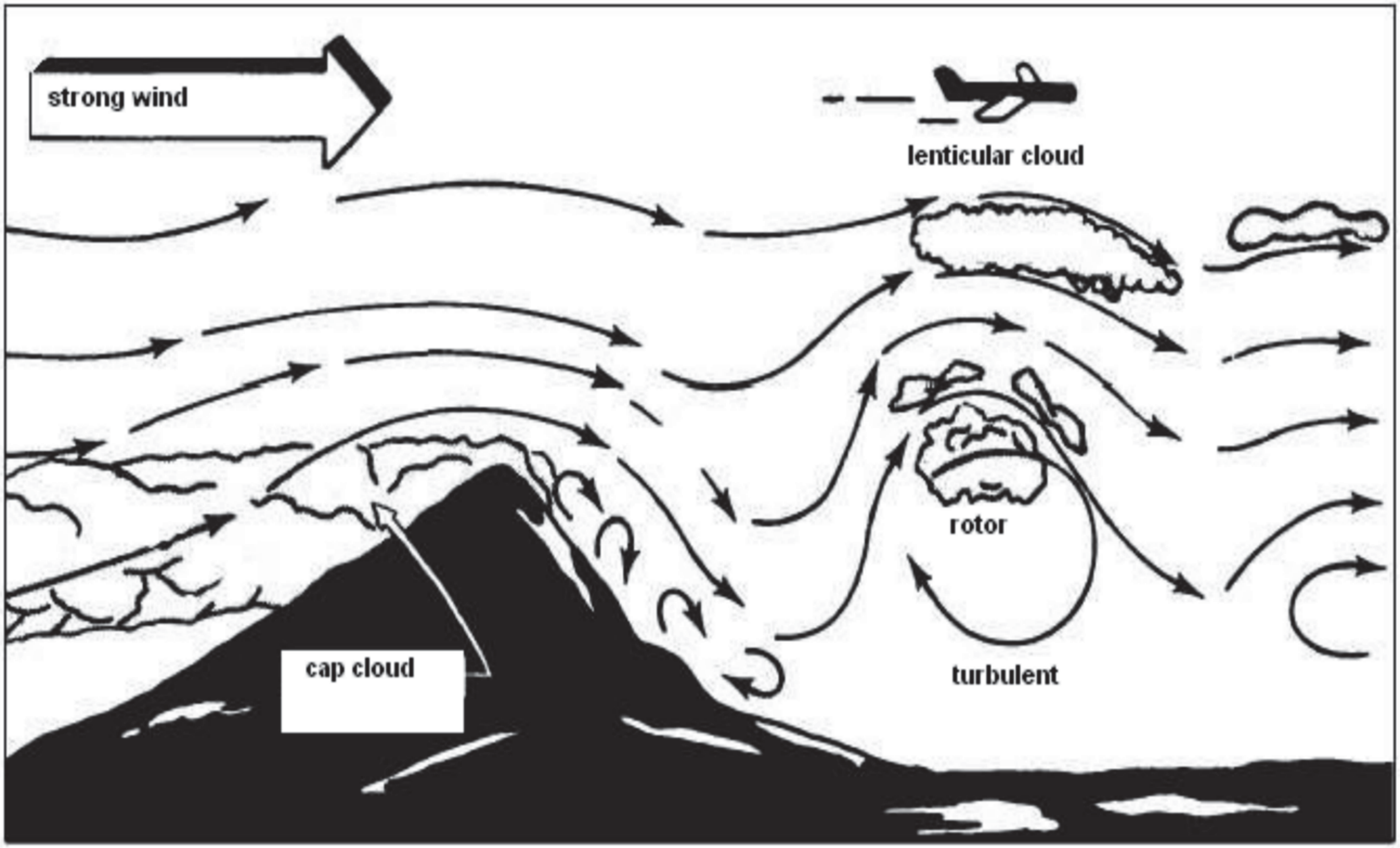

Figure A-3 Mountain Wave

Note. From "Integrated Publishing", 2003, *Aerographer / Meteorology*. Copyright 2003 by Integrated Publishing. Retrieved October 14, 2008, from http://www.tpub.com/weather2/3-25.htm

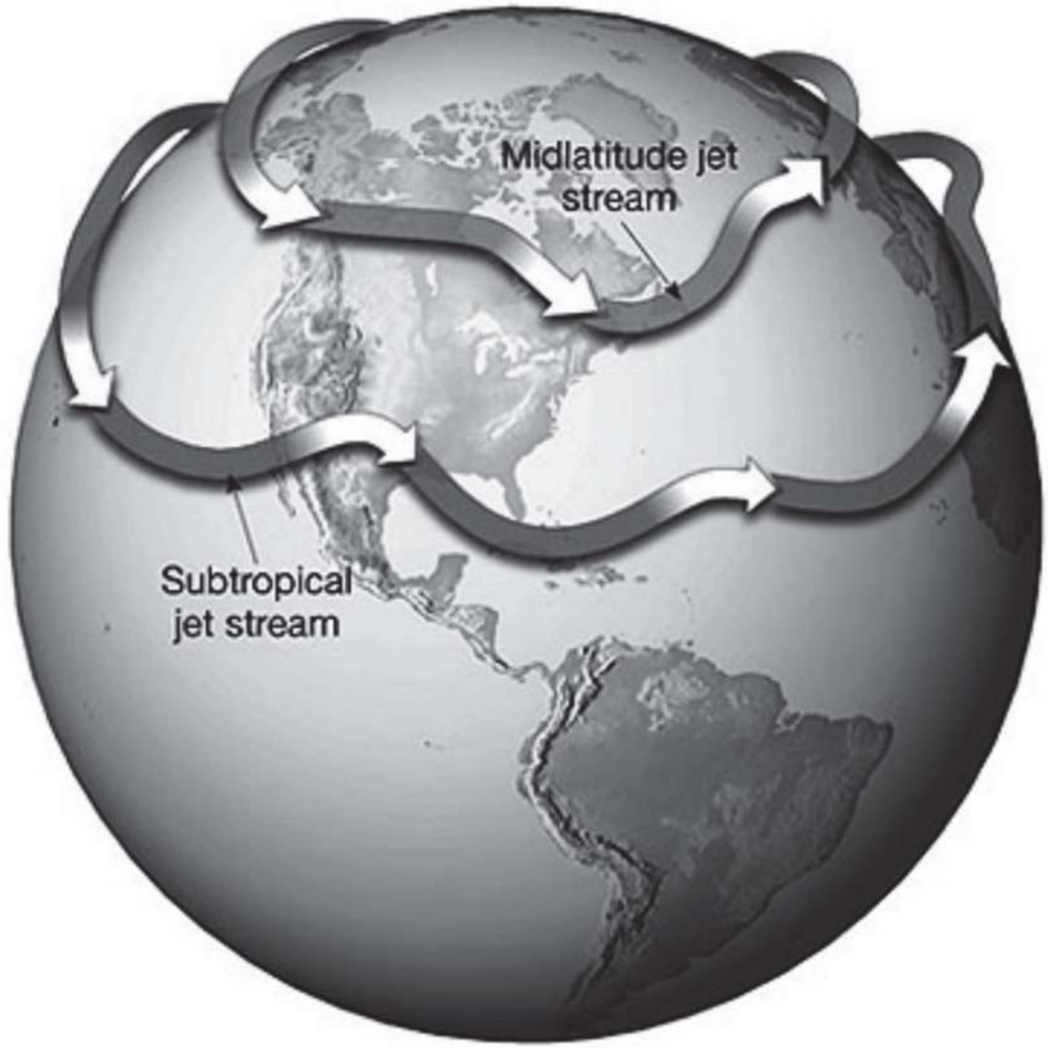

Figure A-4 The Jet Stream

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

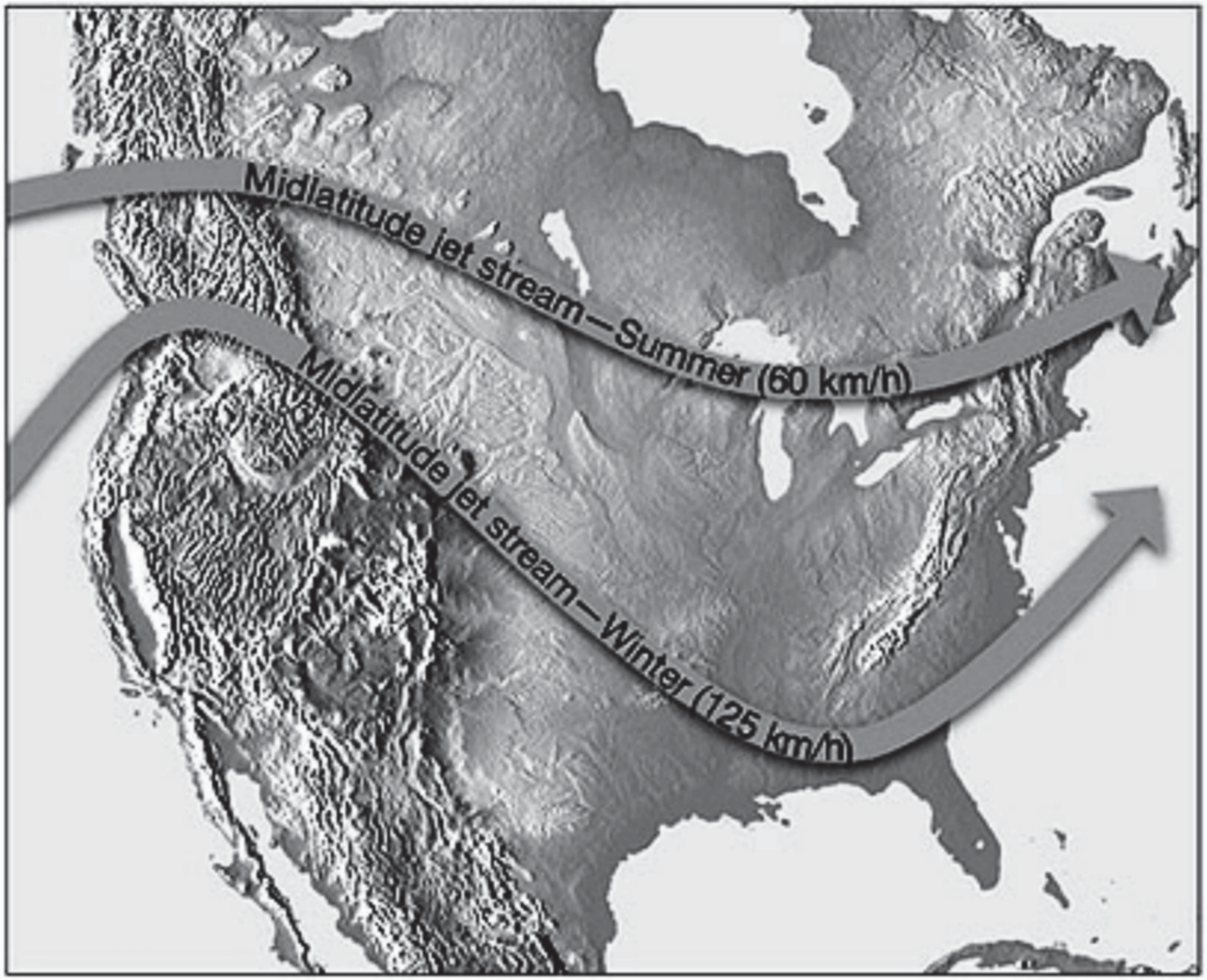

Figure A-5 Seasonal Mid-Latitude Jet Stream

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

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 2

EO M436.02 – DESCRIBE AIR MASSES AND FRONTS

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Review and prepare the demonstration located at Attachment A.

Prepare the slides located at Attachments B and C.

Photocopy the handout located at Attachment D for each cadet.

Prepare the learning stations located at Attachments E–I.

Photocopy a set of the fronts worksheets located at Attachment J for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to orient the cadets to air masses and fronts and generate interest in the subject.

An in-class activity was chosen for TP 3 as it is an interactive way to present types of fronts and associated weather.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to describe air masses and fronts.

IMPORTANCE

It is important for cadets to describe air masses and fronts as knowledge of this material helps them to understand changes in weather conditions. Being able to describe air masses and fronts provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

Teaching Point 1	**Explain weather in an air mass.**
Time: 10 min	Method: Interactive Lecture

WEATHER IN AN AIR MASS

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

- moisture content,
- the cooling process, and
- the stability of the air.

Moisture Content

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

The Cooling Process

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

- contact with a surface cooling by radiation,
- advection over a colder surface, and
- expansion brought about by lifting.

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

The Stability of the Air

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

Characteristics of Cold Air Masses and Warm Air Masses

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

- instability,
- turbulence,
- good visibility,
- cumuliform clouds, and
- precipitation in the form of showers, hail, and thunderstorms.

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

- stability,
- smooth air,
- poor visibility,

- stratiform clouds and fog, and
- precipitation in the form of drizzle.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What are the three main factors that determine weather in an air mass?

Q2. What are the cooling processes that contribute to condensation and the formation of clouds?

Q3. What are the characteristics of a warm air mass?

ANTICIPATED ANSWERS:

A1. Moisture content, the cooling process, and the stability of the air.

A2. Contact with a surface cooling by radiation, advection over a colder surface, and expansion brought about by lifting.

A3. Stability, smooth air, poor visibility, stratiform clouds and fog, and precipitation in the form of drizzle.

Teaching Point 2	**Define and explain types of fronts.**
Time: 15 min	Method: Interactive Lecture

FRONTS

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

Conduct the demonstration outlined at Attachment A to illustrate the mixing of warm and cold air masses:

1. Allow the cadets to move closer so they can observe what will happen.
2. Have the cadets predict what will happen when the divider is removed.
3. Observe the action between the red and blue colored water.

The blue-dyed water represents a cold air mass and the red-dyed water represents a warm air mass. The area where these two air masses meet and mix is a front.

Show the slides located at Attachment B as fronts are presented.

The blue water (colder and more dense) will slide underneath the warmer water which is the same that occurs to the air.

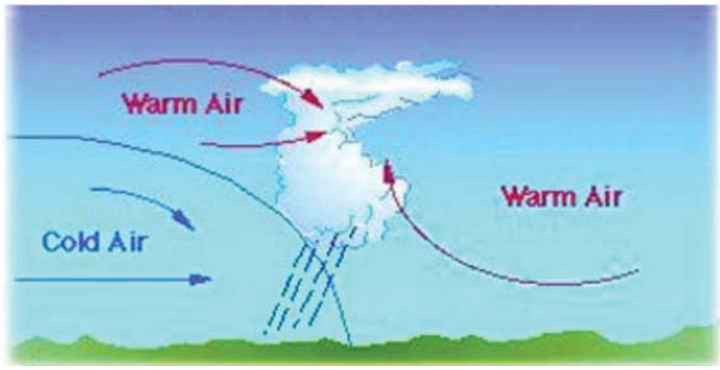

Figure 1 Cold Front

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

The cold air mass is more dense and therefore sinks, undercutting the warm air which will ascend over the cold air.

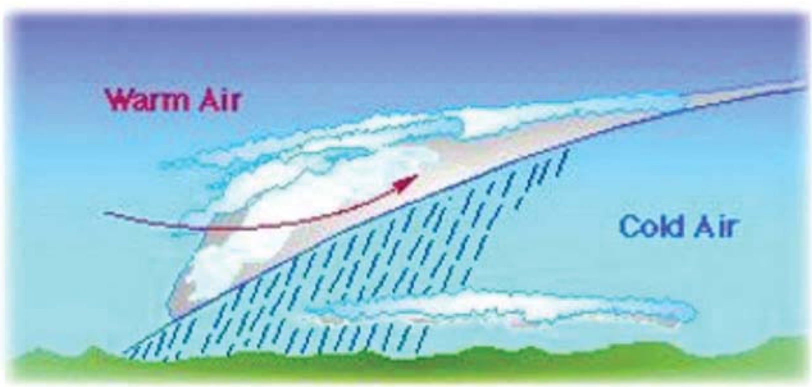

Figure 2 Warm Front

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

Show the slides located at Attachment C as front symbols are presented.

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

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

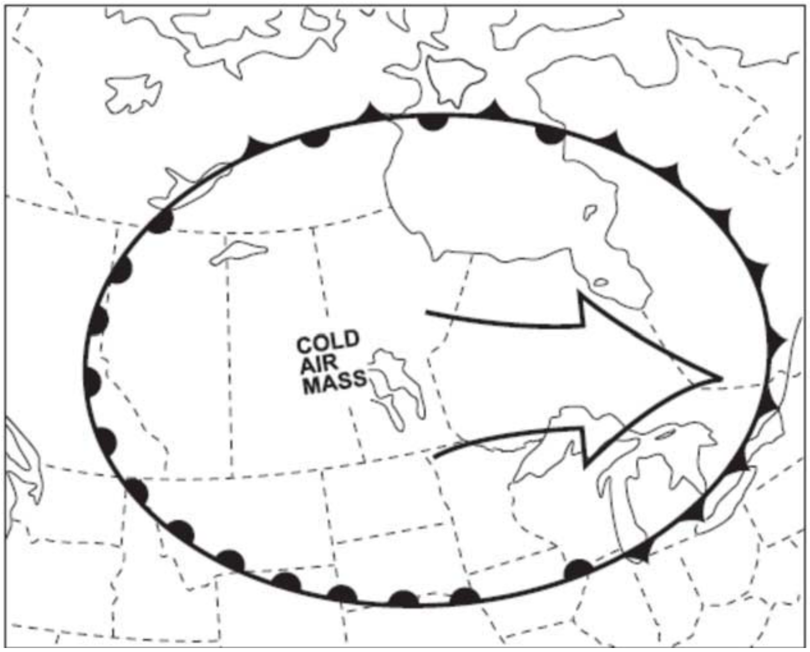

Figure 3 Air Masses and Fronts

Note. From *Air Command Weather Manual* (p. 6-8), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Distribute the handout located at Attachment D to each cadet. Cadets will label each symbol as the information is presented.

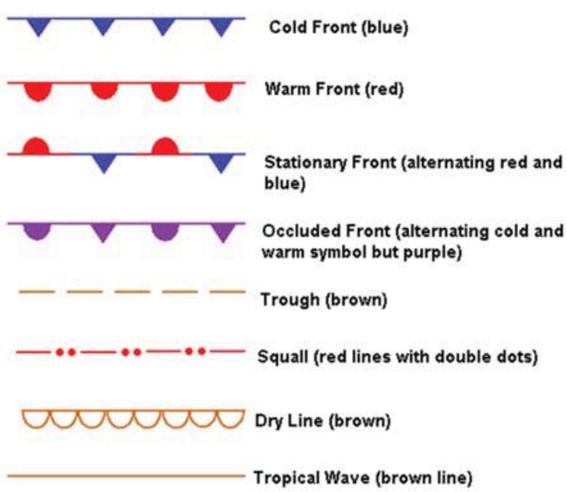

Figure 4 Front Symbols

Note. From "Weather", About.com, by R Oblanck, Copyright 2009 by The New York Times Company. Retrieved February 27, 2009 from http://weather.about.com/od/frontsandairmasses/qt/front_symbols.htm

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. Define a front.

Q2. What does the interaction of air masses along their frontal zones cause?

Q3. Explain what happens when a cold air mass and a warm air mass meet.

ANTICIPATED ANSWERS:

A1. A front is the transition zone between two air masses.

A2. Changes in the weather.

A3. The air in a cold air mass is more dense and therefore sinks, undercutting the warm air. The air in a warm air mass will ascend over the cold air.

Teaching Point 3	**Conduct an in-class activity to describe types of fronts and associated weather.**
Time: 55 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets identify different types of fronts and their associated weather.

RESOURCES

- Pen / pencil,
- Coloured pencils / markers,
- Fronts information sheets located at Attachments E–I, and
- Fronts worksheets located at Attachment J.

ACTIVITY LAYOUT

Set up and clearly mark five learning stations, located at Attachments E–I.

ACTIVITY INSTRUCTIONS

1. Distribute all five fronts worksheets and a pen / pencil to each cadet.
2. Divide the cadets into groups of two or three and place each group at one of the learning stations.
3. Have the cadets fill out the appropriate fronts worksheet for that station.

At learning stations with more than one diagram the cadet can choose which one to draw.

4. After nine minutes have the groups rotate to the next station until each group has completed all five stations.

5. Review the fronts worksheets as a class and answer any questions.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What are the characteristics of a cold air mass?

Q2. What clouds indicate the passing of a warm front?

Q3. What is the term for the wedge-shaped mass of warm air lying above the colder air masses in an occluded front?

ANTICIPATED ANSWERS:

A1. Instability, turbulence, good visibility, cumuliform clouds, and precipitation in the form of showers, hail, and thunderstorms.

A2. Cirrus, cirrostratus, altostratus, nimbostratus, and stratus.

A3. Trowal.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

There are two basic types of weather: air mass and frontal. Knowledge of air masses and fronts is crucial for understanding weather patterns and making accurate predictions of changing weather conditions. This knowledge is essential for future aviation training and for potential instructional duties at the squadron.

INSTRUCTOR NOTES / REMARKS

It is recommended that the three periods required for this EO be scheduled consecutively.

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

A3-044 CFACM 2-700 Air Command. (2001). *Air Command weather manual*. Ottawa, ON: Department of National Defence.

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-334 Short, N. (2005). "Remote Sensing Tutorial". *Federation of American Scientists*. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

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WARM AND COLD FRONT DEMONSTRATION OUTLINE

1. Fill a thermos / cooler / bottle with warm water and another with cold water.

Figure A-1 Air Mass Equipment

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

2. Add a few drops of red food colouring to the bottle with warm water.
3. Add a few drops of blue food colouring to the bottle with cold water.
4. Shake / stir each bottle to evenly mix the colouring and water.
5. Place the empty jars together to ensure an exact match.
6. Fill one jar to almost overflowing with blue-dyed water and the other jar with red-dyed water.

Figure A-2 Jars Filled

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

7. Place an index card or a plastic coated paper on the top of the warm (red-dyed) water jar and press down around the edges of the jar to make a seal.

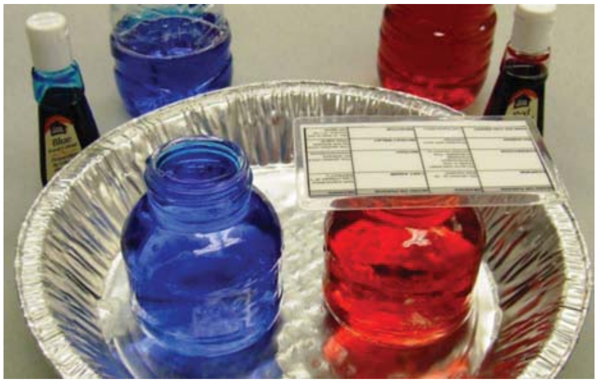

Figure A-3 Card Over Red Jar

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

8. Place the warm water jar over the top of the cold water jar so that the edges meet.

Figure A-4 Jars Stacked with Card Inserted

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

9. Have an assistant gently remove the paper once the jars are stacked on each other, keeping the jars together (do this over a sink or container to catch any water that may leak out).

Figure A-5 Jars Stacked with Card Removed

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

10. Keeping one hand on each jar, slowly turn the jars to one side while holding the centre together.

Figure A-6 Turn Jars on Side

Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

11. Observe the action between the red and blue colored water.

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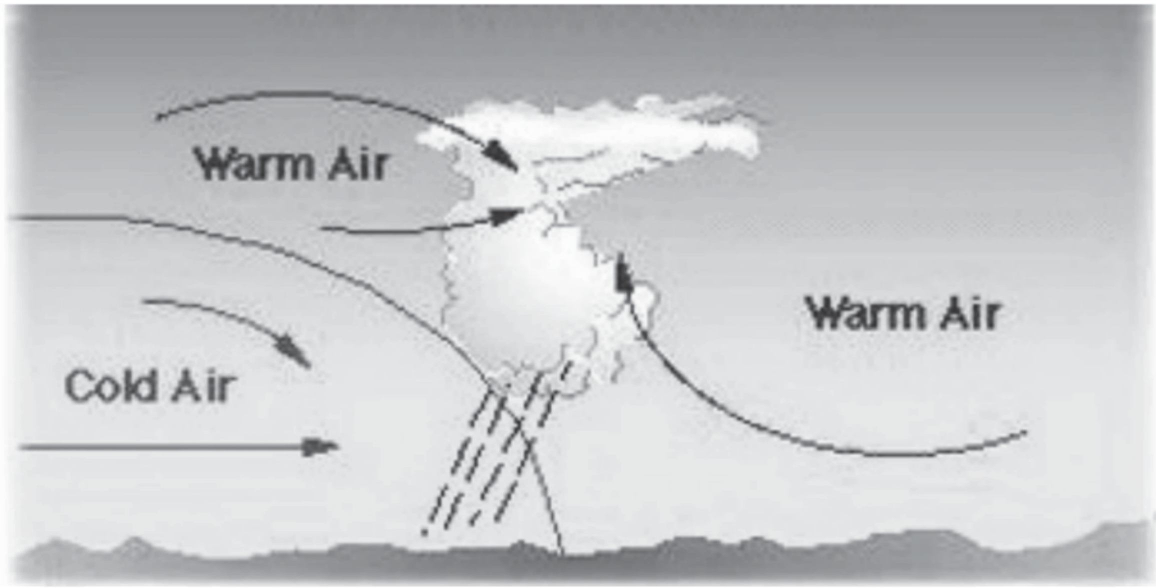

Figure B-1 Cold Front

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

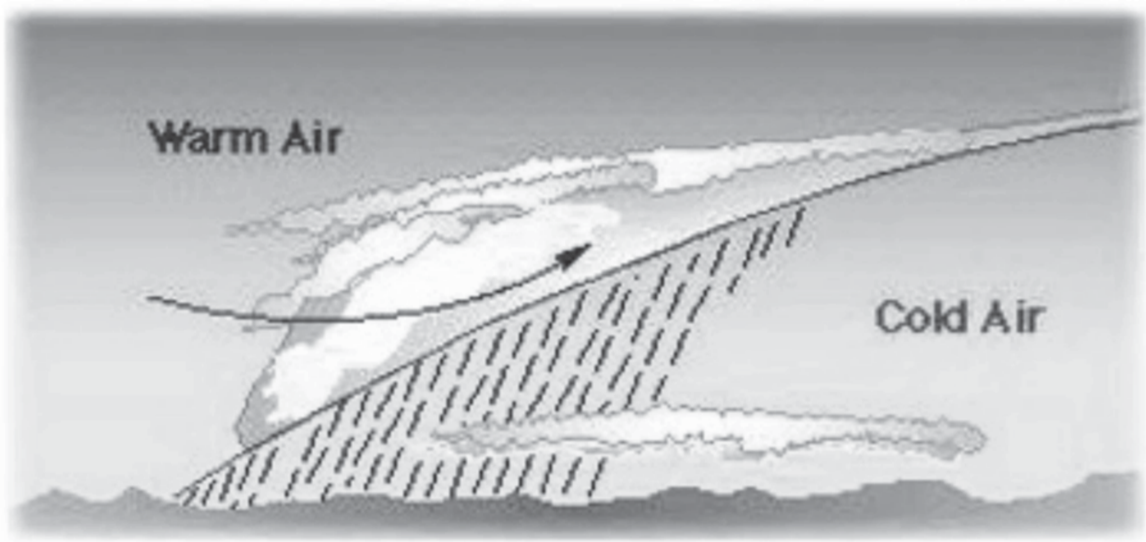

Figure B-2 Warm Front

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

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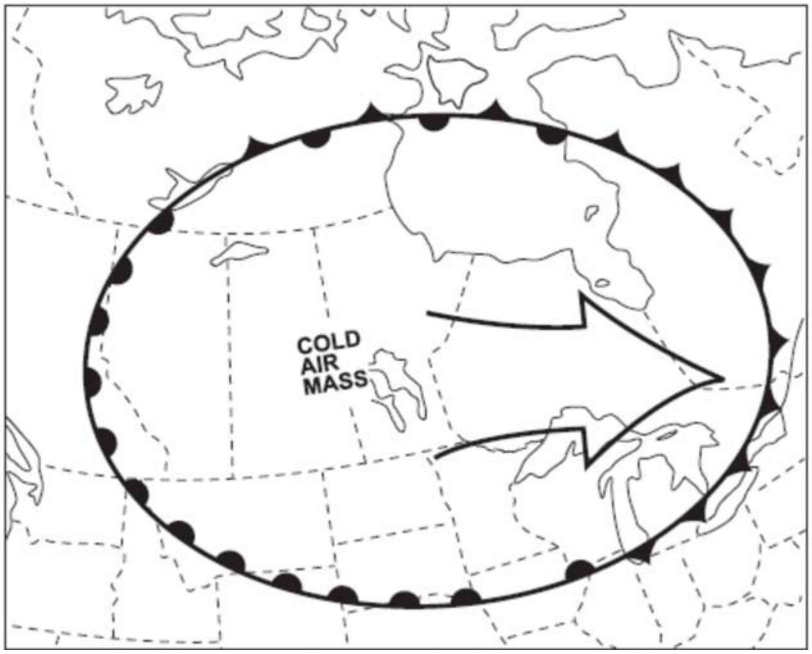

Figure C-1 Air Masses and Fronts

Note. From *Air Command Weather Manual* (p. 6-8), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

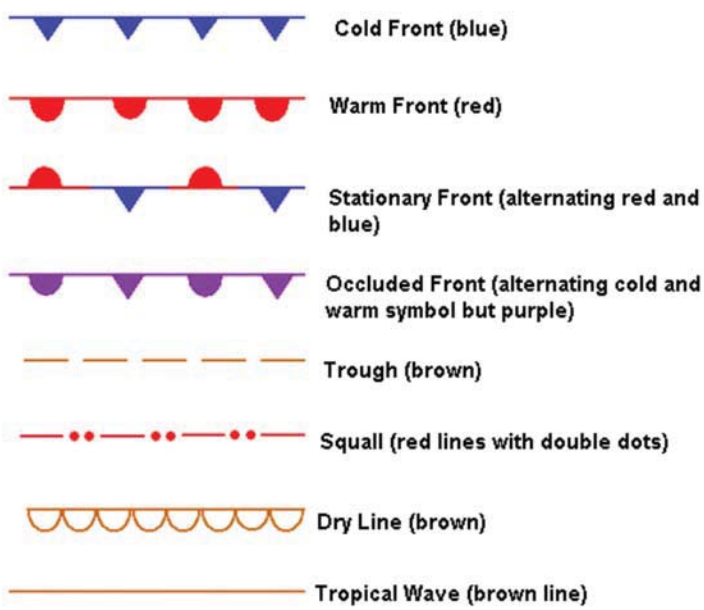

Figure C-2 Front Symbols

Note. From "Weather" About.com, by R Oblanck, Copyright 2009 by The New York Times Company. Retrieved February 27, 2009, from http://weather.about.com/od/frontsandairmasses/qt/front_symbols.htm

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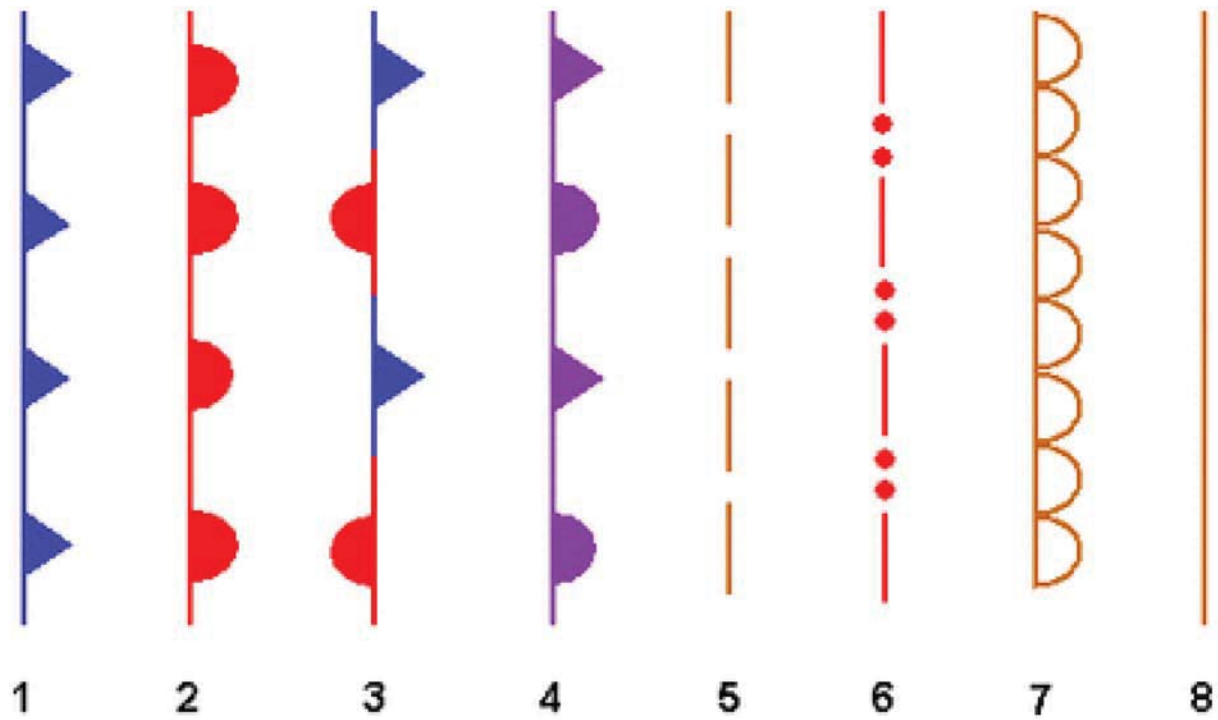
WEATHER MAP SYMBOLS



	Front	Colour
1		
2		
3		
4		
5		
6		
7		
8		

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COLD FRONT

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

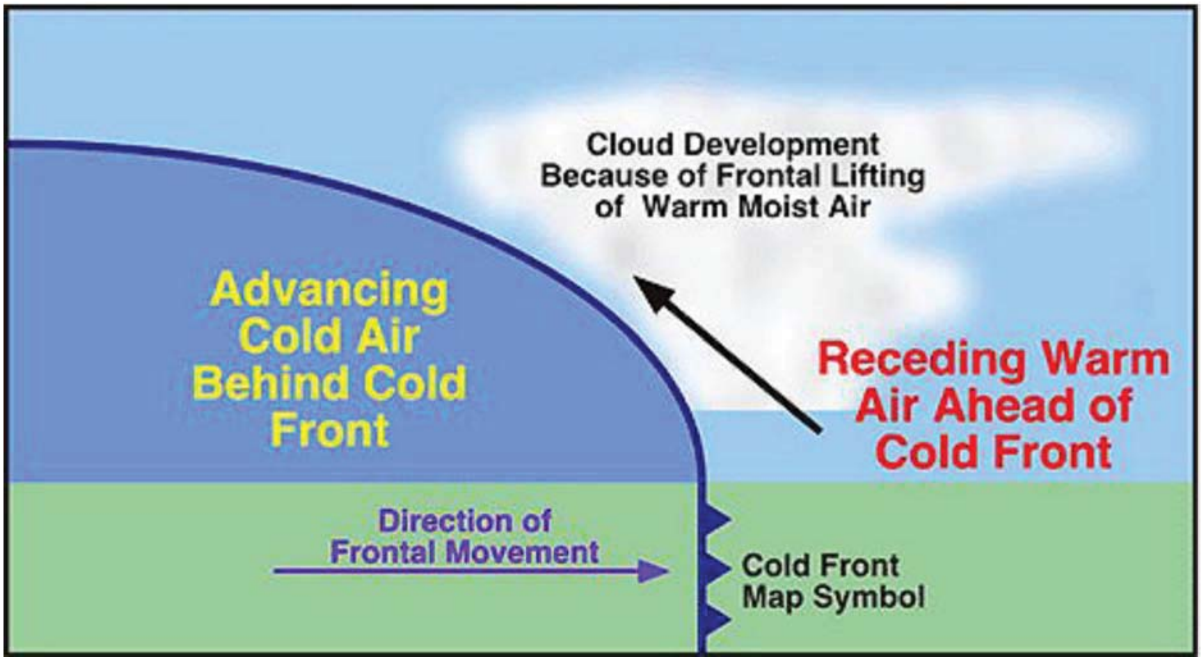

Figure E-1 Cold Front

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

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

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

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

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

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WARM FRONT

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

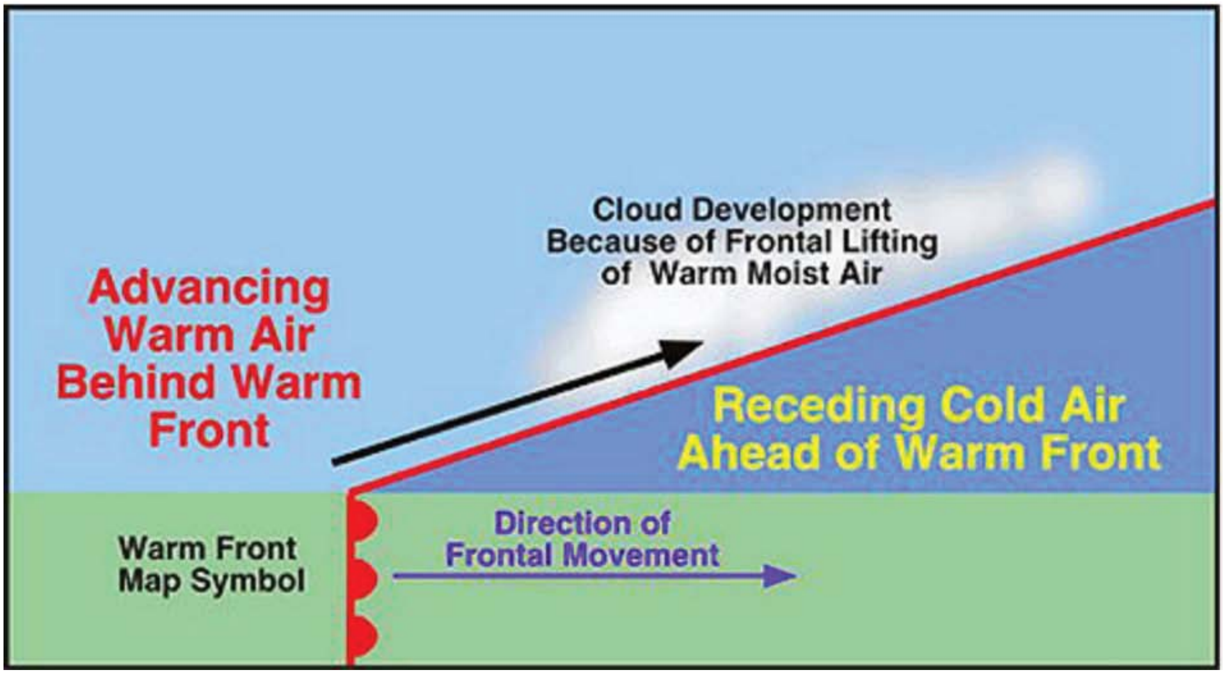

Figure F-1 Warm Front

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

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

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

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

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

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

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

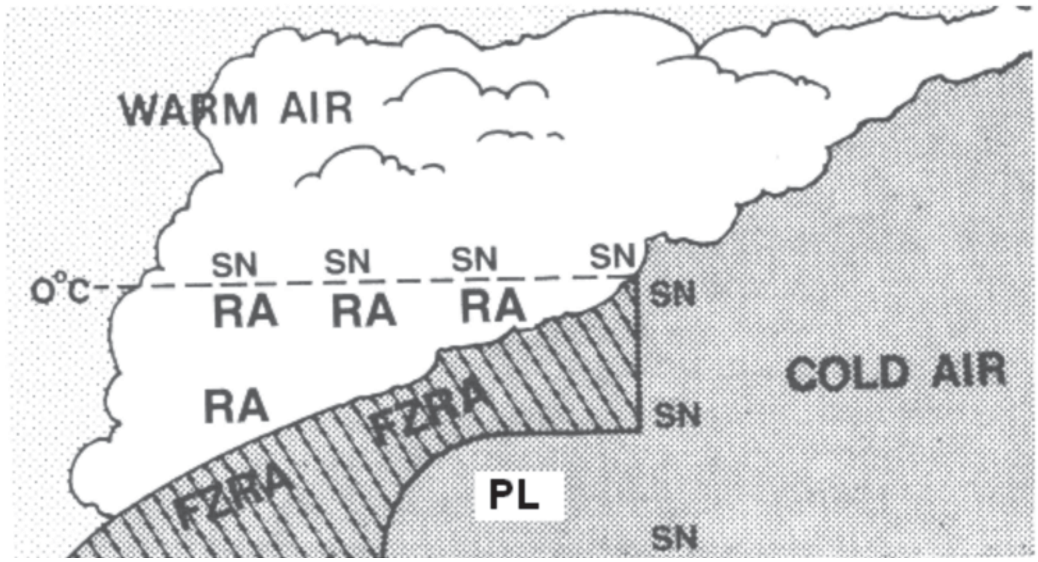

Figure F-2   Precipitation in a Warm Front in Winter

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

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

STATIONARY FRONT

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

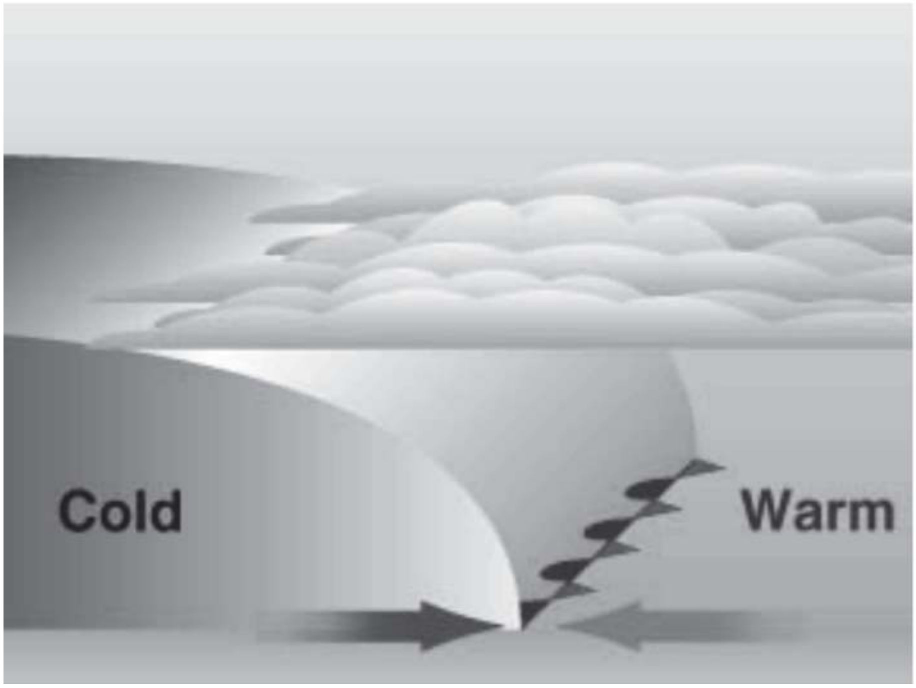

Figure G-1 Stationary Front

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

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

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OCCLUDED FRONTS

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

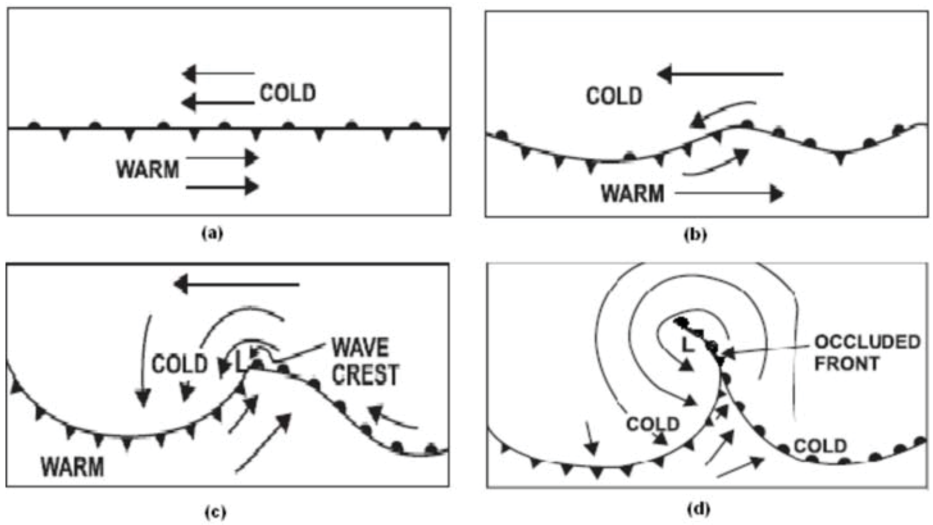

Figure H-1 Occluded Front Formation

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

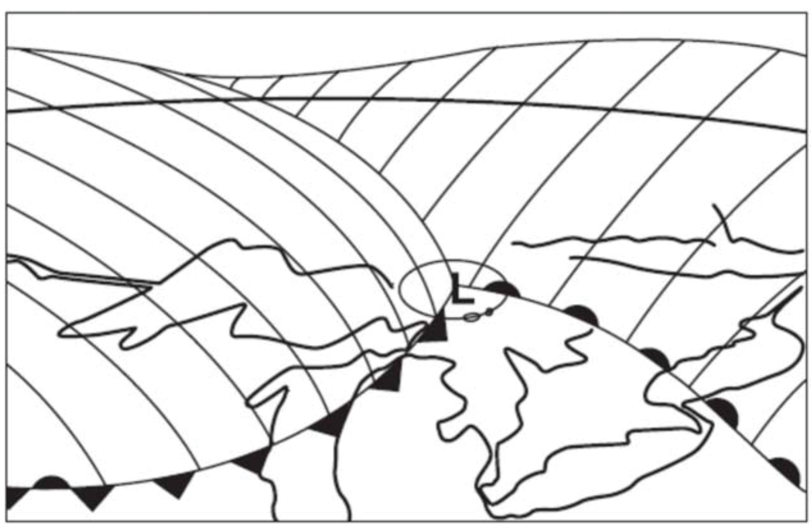

Figure H-2 Frontal Depression

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

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

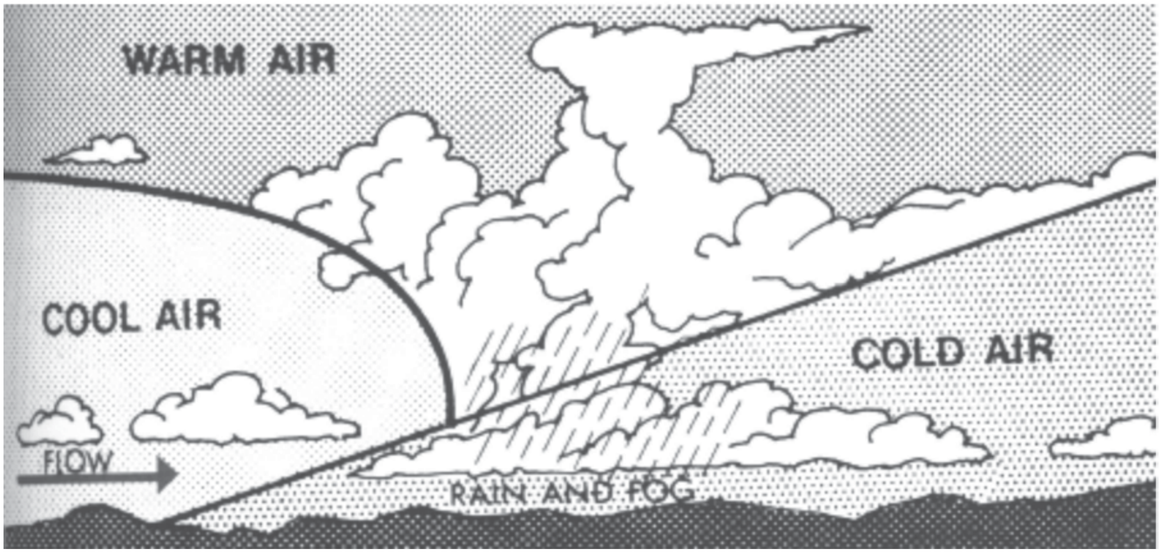

Figure H-3 Warm Occlusion

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

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

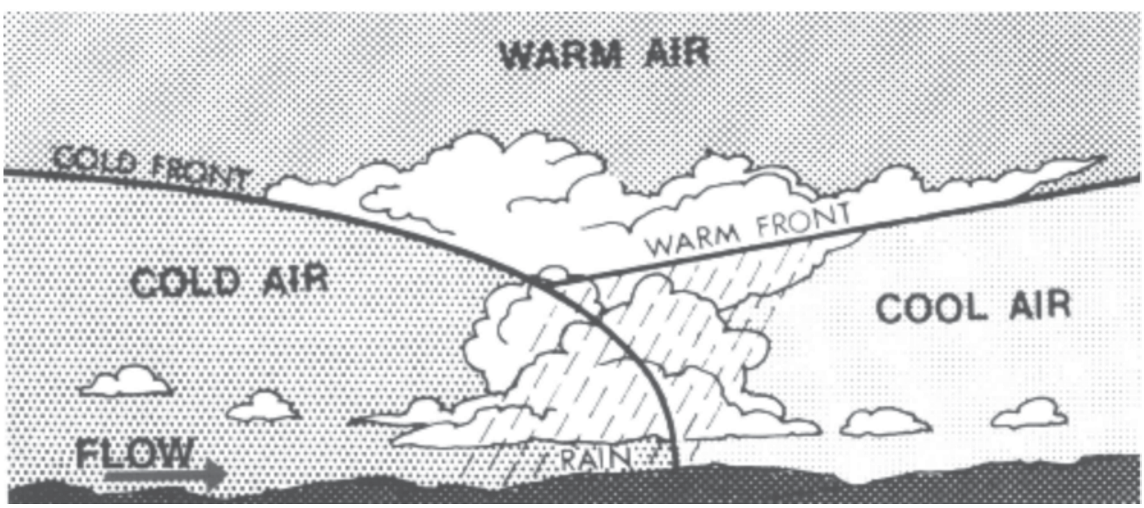

Figure H-4 Cold Occlusion

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

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

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

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UPPER FRONTS

An upper cold front can form in two ways:

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

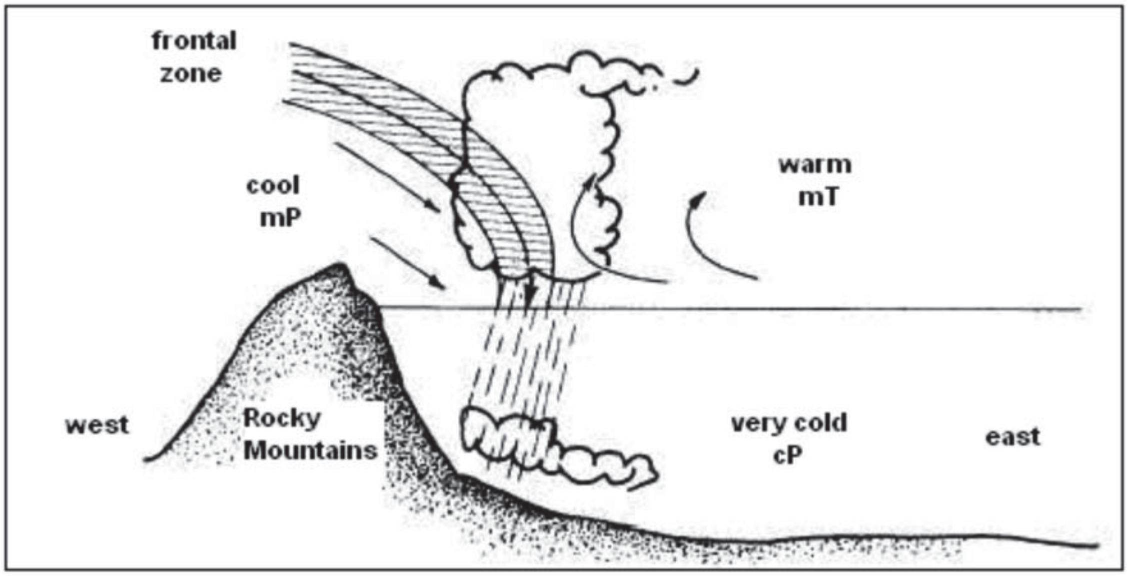

Figure I-1 Upper Cold Front

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

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

An upper warm front can form in two ways:

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

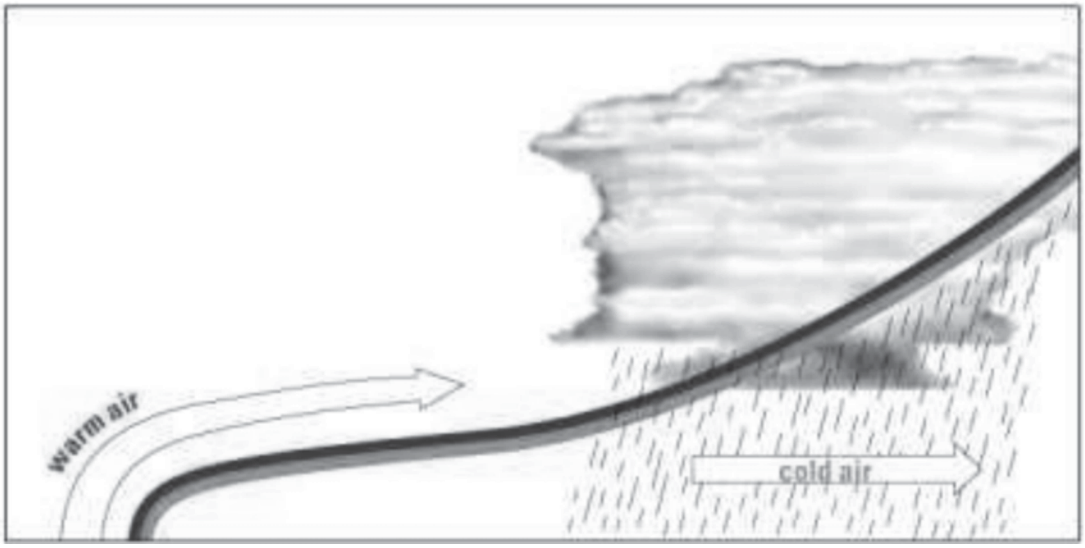

Figure I-2 Upper Warm Front

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

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

COLD FRONT

DEFINITION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

WARM FRONT

DEFINITION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

STATIONARY FRONT

DEFINITION:

____

ASSOCIATED WEATHER:

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INTERESTING FACTS:

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DIAGRAM:

OCCLUDED FRONTS

DEFINITION OF WARM OCCLUSION:

DEFINITION OF COLD OCCLUSION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

UPPER FRONTS

UPPER COLD FRONT FORMATION:

1. ______________________________

____

2. ______________________________

____

UPPER WARM FRONT FORMATION:

1. ______________________________

____

2. ______________________________

____

ASSOCIATED WEATHER:

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DIAGRAM:

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 3

EO C436.01 – EXPLAIN FOG

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Acquire jars, strainers, and oven mitts (1 pair per group) for each group in TP 1.

Obtain three or four ice cubes for each group for TP 1.

Use a kettle(s) to boil water for each group for TP 1.

Prepare slides or handouts located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An in-class activity was chosen for this lesson as it is an interactive way to present the formation and types of fog.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain fog.

IMPORTANCE

Fog is one of the most common and persistent weather hazards encountered in aviation which impedes a pilot's visibility. Being able to explain fog provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

Teaching Point 1	Have the cadets perform an experiment to illustrate the formation of fog.
Time: 10 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadet demonstrate how fog forms.

RESOURCES

- Glass jars,
- Strainers,
- Oven mitts,
- Kettle,
- Water,
- Rubbing alcohol, and
- Ice cubes.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into groups of two to four.
2. Use a kettle to boil water for each group.
3. Distribute resources to each group.
4. Briefly explain the steps of the experiment below and have the cadets make a hypothesis regarding the outcome.
5. Have each group perform the following experiment:
   a. Fill the jar completely with hot water and let it stand for one minute.
   b. Using oven mitts pour out all but 3 cm of water from the jar.
   c. Add three to four drops of rubbing alcohol to water.
   d. Put the strainer over the top of the jar.
   e. Place three or four ice cubes in the strainer.
   f. Observe the results.
6. Give the groups time to discuss what they have observed.
7. Ask the cadets to provide an explanation of what has happened.

The warm, moist air is cooled by the ice cubes to a temperature below its dewpoint, causing the water vapour to condense and form a cloud. A cloud in contact with the ground is called fog.

Fog can also form when the dewpoint is raised to the air temperature through the addition of water vapour.

The following are the ideal conditions for the formation of fog:

- an abundance of condensation nuclei,
- high relative humidity,
- a small temperature dewpoint spread, and
- some cooling process to initiate condensation.

Fog is usually dissipated by heating from below as sunlight filters down through the fog layer.

SAFETY

- Warn the cadets the water is hot and may cause burns.
- Ensure the cadets use oven mitts and caution when pouring the hot water.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 2	**Conduct an in-class activity to explain types of fog.**
Time: 15 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets explain types of fog.

RESOURCES

- Flip chart paper,
- Flip chart markers, and
- *From the Ground Up: Millennium Edition*.

ACTIVITY LAYOUT

Arrange the classroom for group work.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into four groups.
2. Assign a leader in each group. The group leader will be responsible for assigning tasks to fellow cadets. Each group will need a recorder and at least one presenter.
3. Distribute flip chart paper and flip chart markers to each group.
4. Assign each group one of the following:
   a. radiation fog,
   b. advection fog,
   c. upslope fog and steam fog, and
   d. precipitation-induced fog and ice fog.
5. Have each group prepare a two-minute presentation on their type of fog using *From the Ground Up: Millennium Edition*, p. 147 as a reference.

Encourage the cadets to be creative and draw diagrams of the formation of their types of fog.

6. Have each group deliver their presentation.

Give handouts to each cadet or show slides located at Attachment A.

7. Answer any questions about the types of fog.

The types of fog can easily be remembered using the mnemonic "RAIS UP", as in "RAIS UP da roof".

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What conditions are ideal for the formation of radiation fog?

Q2. The drifting of warm, moist air over a colder land or sea surface causes which type of fog?

Q3. Explain the formation of steam fog.

ANTICIPATED ANSWERS:

A1. Light wind, clear skies, and an abundance of condensation nuclei.

A2. Advection fog.

A3. Steam fog is formed when cold air passes over a warm water surface. Evaporation of the water into the cold air occurs until the cold air becomes saturated. The excess water vapour condenses as fog.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is fog?

Q2. What are the two basic ways in which fog is formed?

Q3. What type of fog is associated mostly with warm fronts?

ANTICIPATED ANSWERS:

A1. Fog is a cloud in contact with the ground.

A2. Fog is formed in the following ways:

- warm, moist air is cooled to a temperature below its dewpoint, causing the water vapour to condense and form a cloud; or
- the dewpoint is raised to the air temperature through the addition of water vapour.

A3. Precipitation-induced fog.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

A good lookout is one of the most important aspects of airmanship when flying under Visual Flight Rules, making visibility from the cockpit a key factor in flight. Fog is one of the most common and persistent weather hazards encountered in aviation which impedes a pilot's visibility. An understanding of fog and the conditions under which it forms is essential for future aviation training.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-200 Weather Wiz Kids. (2008). *Make fog*. Retrieved September 26, 2008, from http://www.weatherwizkids.com/fog.htm

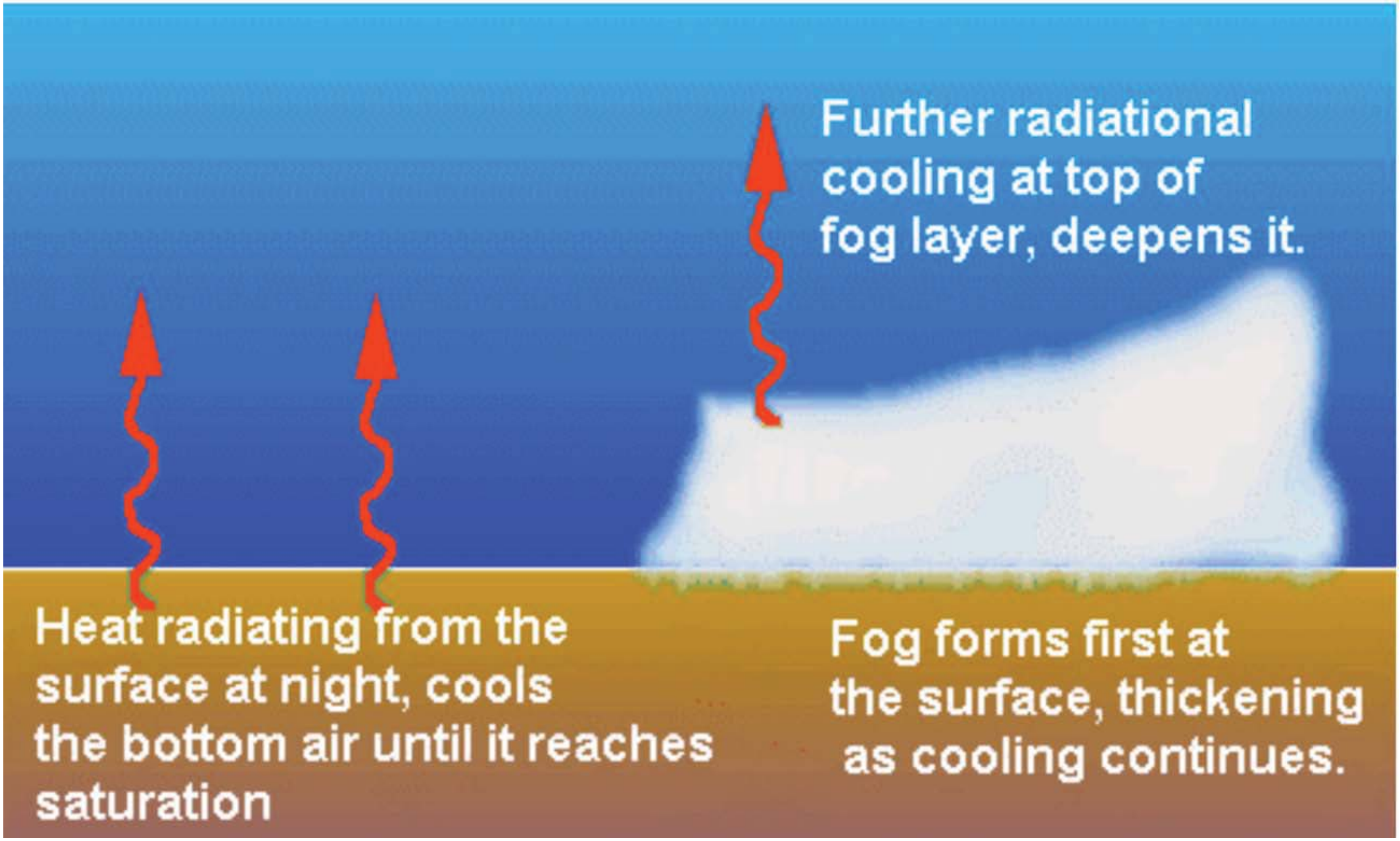

Figure A-1 Radiation Fog

Note. From The Fog Rolls In, 2002, *Weather Almanac for September*. Copyright 2002 by The Weather Doctor. Retrieved March 2, 2009, from http://www.islandnet.com/~see/weather/almanac/arc2002/alm02sep.htm

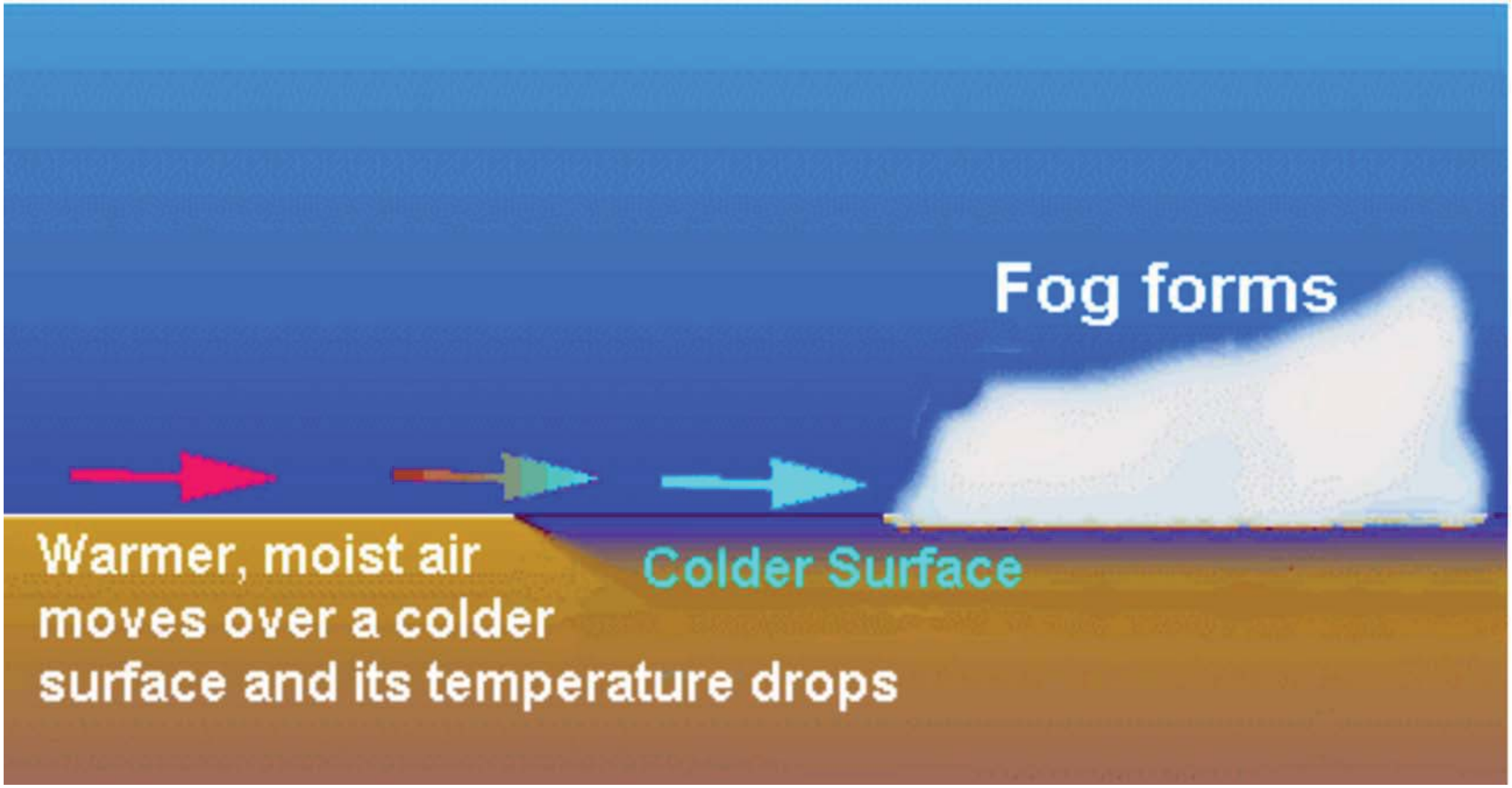

Figure A-2 Advection Fog

Note. From The Fog Rolls In, 2002, *Weather Almanac for September*. Copyright 2002 by The Weather Doctor. Retrieved March 2, 2009, from http://www.islandnet.com/~see/weather/almanac/arc2002/alm02sep.htm

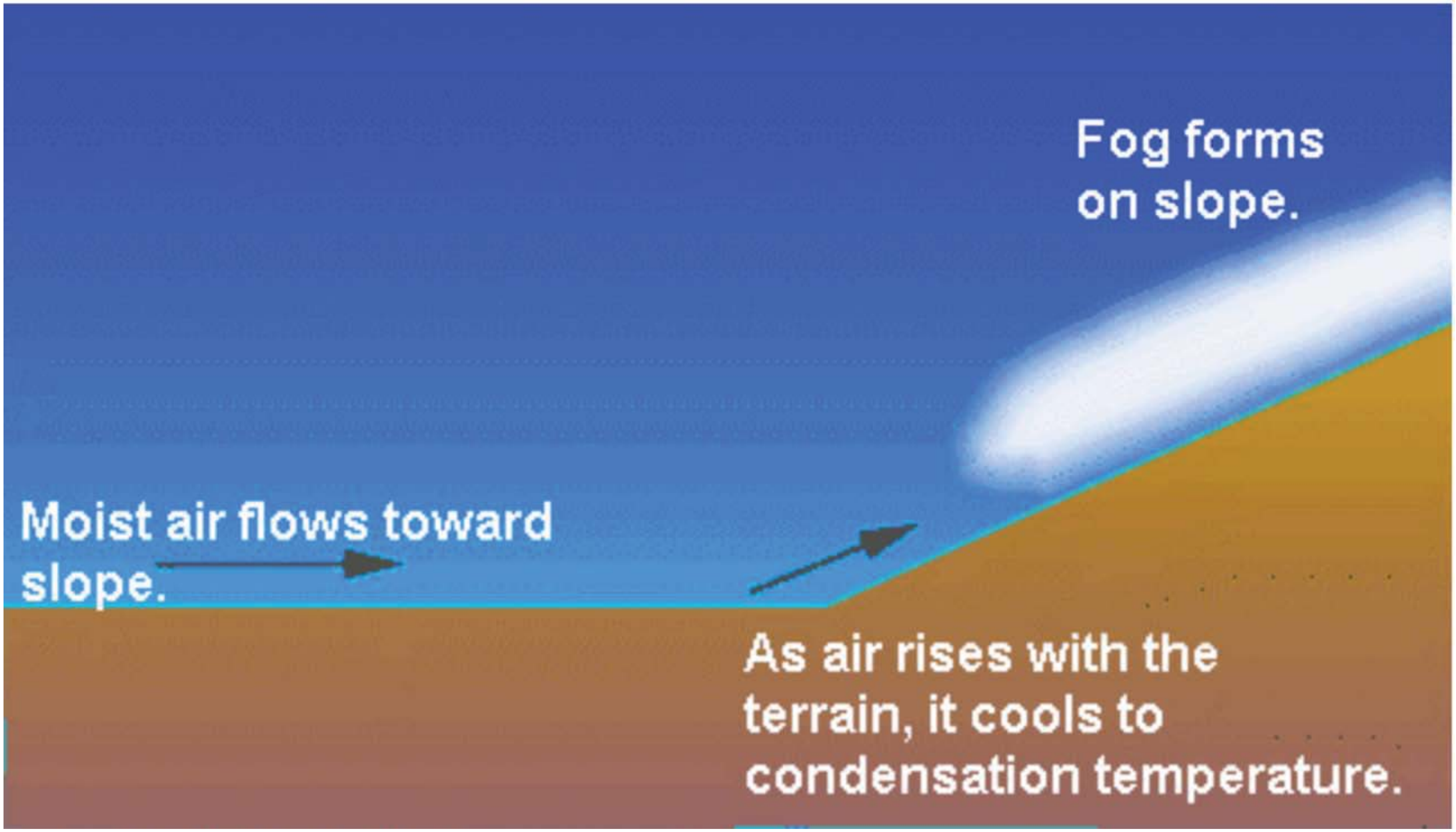

Figure A-3 Upslope Fog

Note. From The Fog Rolls In, 2002, *Weather Almanac for September*. Copyright 2002 by The Weather Doctor. Retrieved March 2, 2009, from http://www.islandnet.com/~see/weather/almanac/arc2002/alm02sep.htm

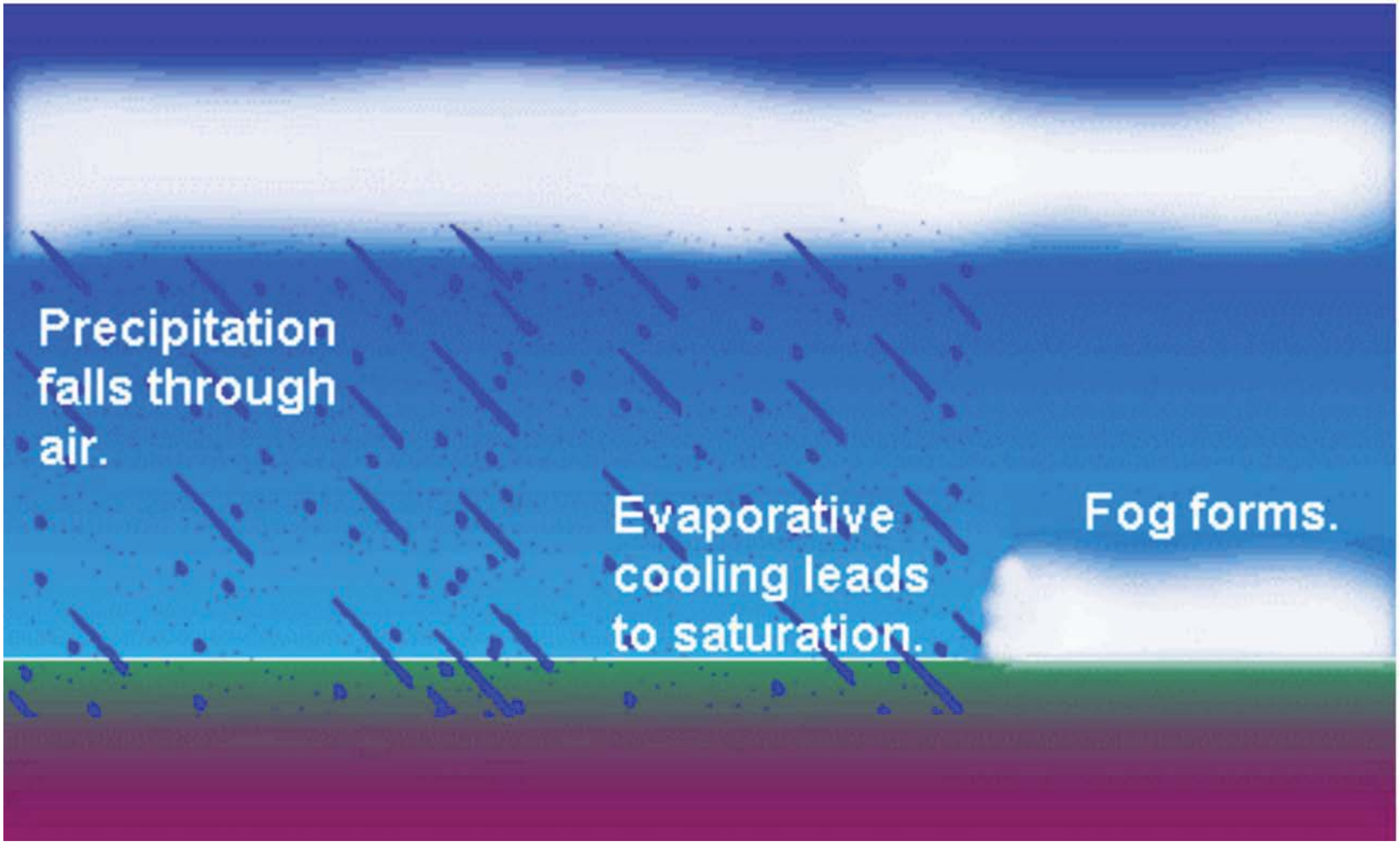

Figure A-4 Precipitation-Induced Fog

Note. From The Fog Rolls In, 2002, *Weather Almanac for September*. Copyright 2002 by The Weather Doctor. Retrieved March 2, 2009, from http://www.islandnet.com/~see/weather/almanac/arc2002/alm02sep.htm

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 4

EO C436.02 – DESCRIBE SEVERE WEATHER CONDITONS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four, Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides located at Attachment A.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadet to severe weather conditions and to generate interest.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to describe severe weather conditions.

IMPORTANCE

It is important for cadets to describe severe weather conditions as knowledge of this material is essential for future aviation training and potential instructional duties at the squadron.

Teaching Point 1	**Describe thunderstorms.**
Time: 10 min	Method: Interactive Lecture

THUNDERSTORMS

Formation

The requirements for the formation of a thunderstorm are the following:

- unstable air,
- high moisture content, and
- some form of lifting agent.

The intensity of these conditions is the difference between a harmless cumulus cloud and a violent thunderstorm. Such unstable atmospheric conditions may be brought about when air is heated from below (convection), forced to ascend the side of a mountain (orographic lift), or lifted over a frontal surface (frontal lift).

Show slide of Figure A-1.

There are three distinct stages of a thunderstorm:

1. cumulus,
2. mature, and
3. dissipating.

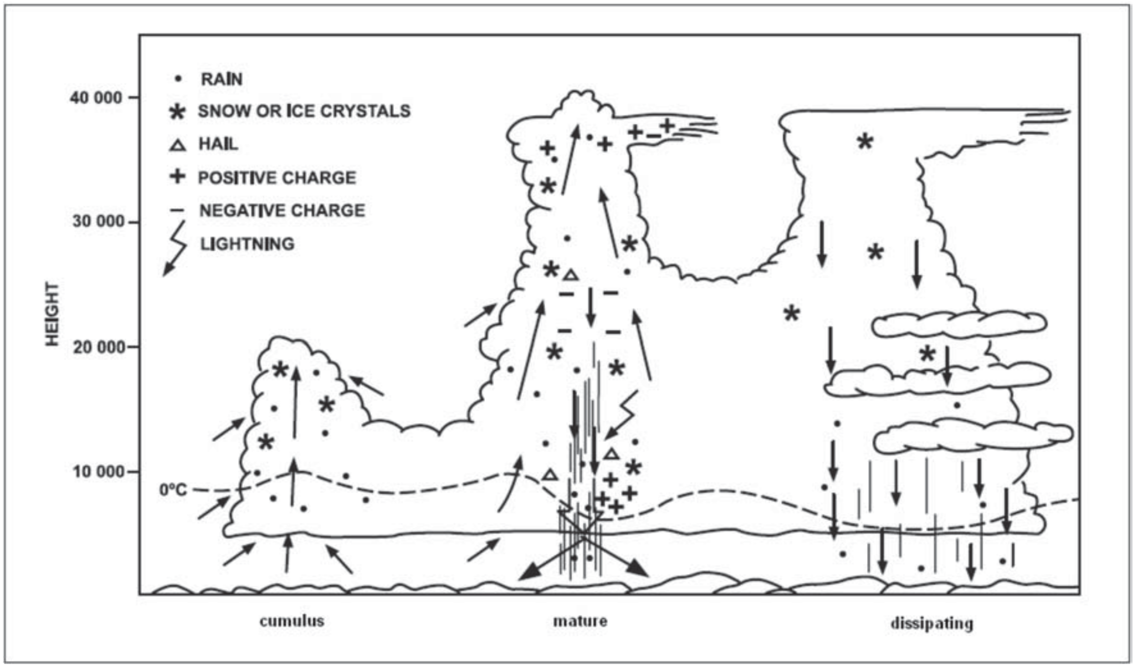

Figure 1 Stages of a Thunderstorm

Note. From *Air Command Weather Manual* (p. 15-2), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Every thunderstorm begins as a cumulus cloud. Strong updrafts, due to the unstable air and lifting agent cause the cloud to build rapidly into a towering cumulus and then cumulonimbus cloud. There is usually no precipitation in this stage as the water droplets and ice crystals are kept suspended in the cloud by the strong updrafts.

In the mature stage, the cumulonimbus cloud may reach heights up to 60 000 feet, with updrafts of 6 000 feet per minute and downdrafts of 2 000 feet per minute. Precipitation, violent turbulence, and thunder and lightning are all associated with thunderstorms in their mature stage.

The precipitation tends to cool the lower region of the cloud causing the thunderstorm cell to dissipate. The downdrafts spread throughout the whole cell except for a small portion at the top where updrafts still occur. The rainfall gradually ceases and the top of the cell spreads out into an anvil shape.

Dangers

Show slide of Figure A-2.

The dangers of flying in or close to a thunderstorm are:

- severe turbulence,
- lightning,
- hail,
- icing,

- unreliable altimeter readings due to rapid changes in pressure,
- strong wind gusts, and
- heavy rain.

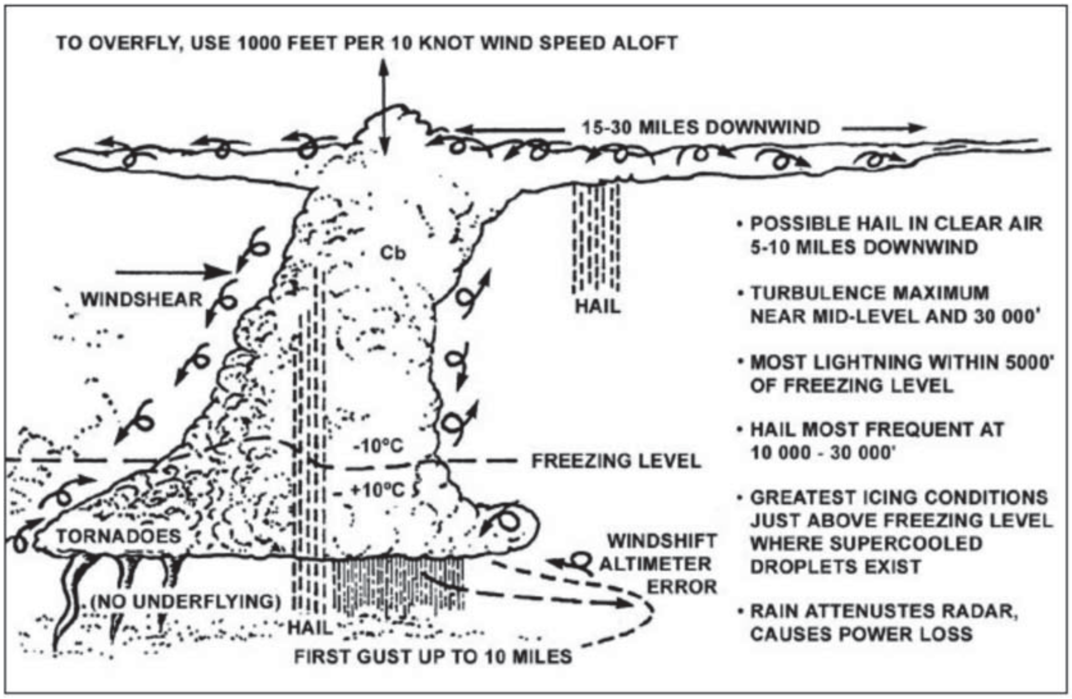

Figure 2 Thunderstorm Dangers

Note. From *Air Command Weather Manual* (p. 15-2), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Avoidance

Stay at least five miles away from a thunderstorm. When flying around a thunderstorm, fly to the right side of it as the wind is circulating counter-clockwise around the low pressure area. Never fly through a thunderstorm in a light aircraft.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What are the requirements for the formation of a thunderstorm?

Q2. In which stage of a thunderstorm will the top of the cumulonimbus cloud take on an anvil shape?

Q3. What are three of the dangers associated with thunderstorms?

ANTICIPATED ANSWERS:

A1. Unstable air, high moisture content, and some form of lifting agent.

A2. The dissipating stage.

A3. Cadets may give any three of the following answers:

- severe turbulence,
- lightning,
- hail,
- icing,
- unreliable altimeter readings due to rapid changes in pressure,
- strong wind gusts, and
- heavy rain.

Teaching Point 2	**Describe icing.**
Time: 5 min	Method: Interactive Lecture

ICING

When an airplane flies at an altitude where the outside air temperature is at or below freezing and strikes a supercooled water droplet, the droplet will freeze and adhere to the airplane. This can occur in cloud, freezing rain, or freezing drizzle. Icing can also occur in clear air through sublimation.

Types of Icing

There are three main types of icing:

- clear ice,
- rime ice, and
- frost.

Show slide of Figure A-3.

Clear ice is a heavy coating of glassy ice which forms when flying in dense cloud or freezing rain. It forms when only a small part of the supercooled water droplet freezes on impact, with the rest of the droplet spreading out and freezing slowly. Clear ice is the most dangerous form of icing because of the following:

- loss of lift due to the altered camber of the wing,
- increase in drag due to the enlarged profile area of the wings,
- increase in weight due to the large mass of ice, and
- the vibration caused by the unequal loading on the wings and propeller blades.

Rime ice is an opaque (milky white) deposit of ice. Rime ice forms when the aircraft skin is at a temperature below zero degrees Celsius, causing the water droplet to freeze completely on contact. Although rime ice is light, it is dangerous due to the aerodynamic alteration of the wing camber and the interference it causes with the carburetor and pitot static system.

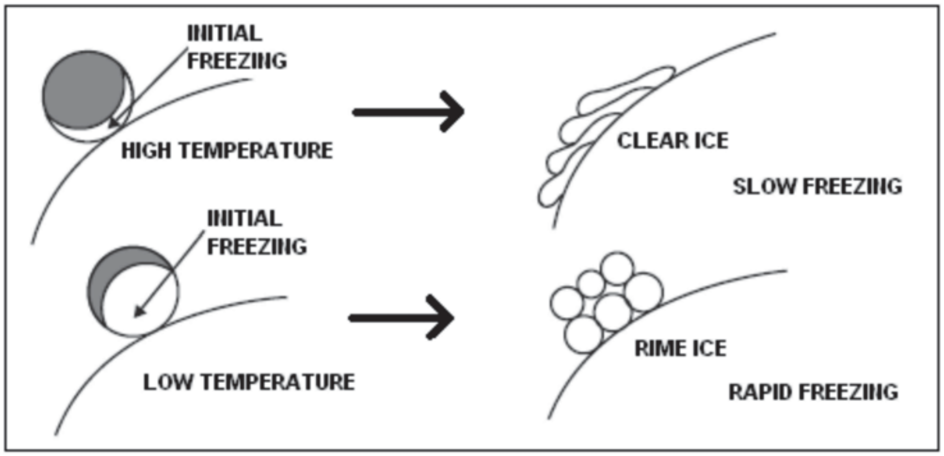

Figure 3 Clear Ice and Rime Ice

Note. From *Air Command Weather Manual* (p. 9-4), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Frost is a white semi-crystalline form of icing which forms in clear air by the process of sublimation. It generally forms on two occasions:

- when a cold aircraft enters warmer and damper air during a steep descent; and
- when an aircraft parked outside on a clear cold night cools by radiation to a temperature below that of the surrounding air.

Frost should be removed before takeoff as it will reduce lift and increase the stall speed of the aircraft.

Show slide of Figure A-4.

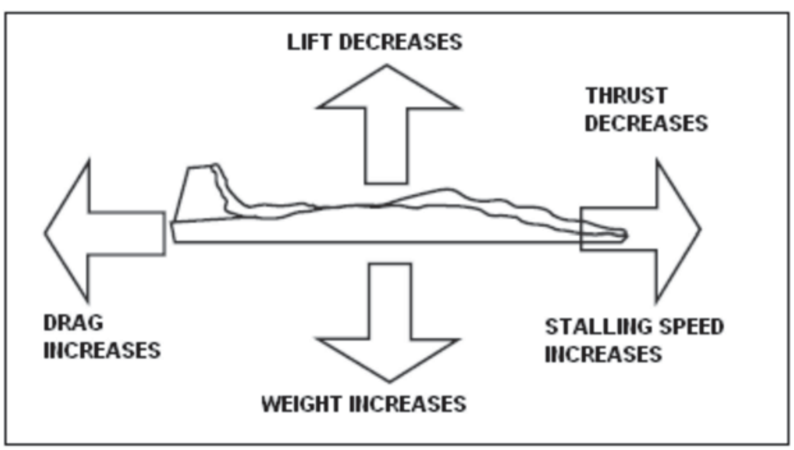

Figure 4 Effects of Icing

Note. From *Air Command Weather Manual* (p. 9-1), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Protection From Icing

Many modern airplanes are fitted with various systems designed to prevent ice from forming or to remove ice after it has formed. Three of these systems are:

- fluids,
- rubber boots, and
- heating devices.

Fluids with a low freezing point are released over the blades of the propellers and the surfaces of the wings to prevent icing.

Show slide of Figure A-5.

Rubber boots are membranes of rubber attached to the leading edges that can pulsate in such a way that ice is cracked and broken off after it has formed.

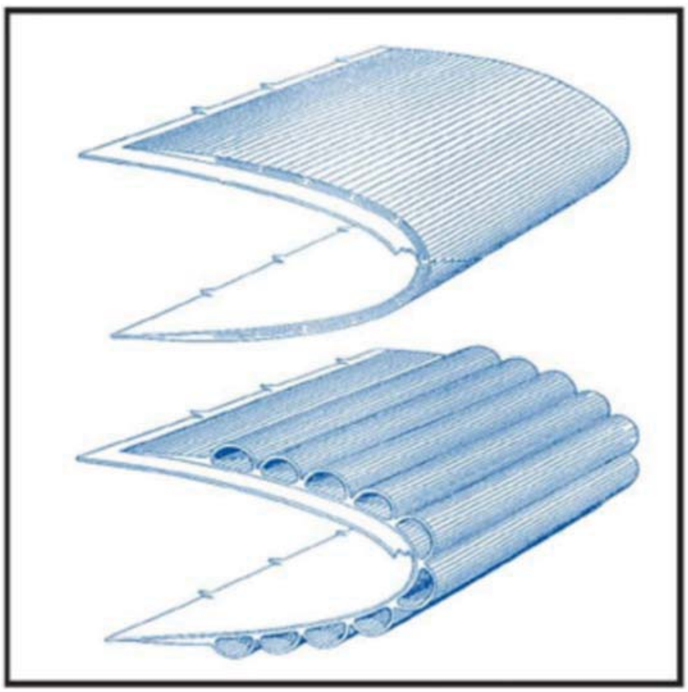

Figure 5 Rubber Boots

Note. From "Icing Conditions in Flight", *Pilot Friend*. Retrieved October 22, 2008, from http://www.pilotfriend.com/safe/safety/icing_conditions.htm

Heating vulnerable areas with hot air from the engine or special heaters prevents the buildup of ice.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. How can a pilot tell the difference between clear ice and rime ice?

Q2. How does frost form?

Q3. What are three methods of protection from icing?

ANTICIPATED ANSWERS:

A1. Clear ice is glassy while rime ice is opaque.

A2. Frost forms through sublimation.

A3. Fluids, rubber boots, and heating devices.

Teaching Point 3	**Describe types of turbulence.**
Time: 10 min	Method: Interactive Lecture

TYPES OF TURBULENCE

Turbulence is an irregular motion of the air resulting from eddies and vertical currents. It is one of the most unpredictable of all the weather phenomena.

There are four types of turbulence:

- mechanical turbulence,
- thermal turbulence,
- frontal turbulence, and
- wind shear.

Show slides of Figures A-6 and A-7.

Mechanical Turbulence

Mechanical turbulence is caused by friction between the air and the ground. The intensity of mechanical turbulence depends on the strength of the surface wind, the nature of the terrain, and the stability of the air. Strong winds, rough terrain, and very unstable air create greater turbulence. Mountain waves produce some of the most severe mechanical turbulence.

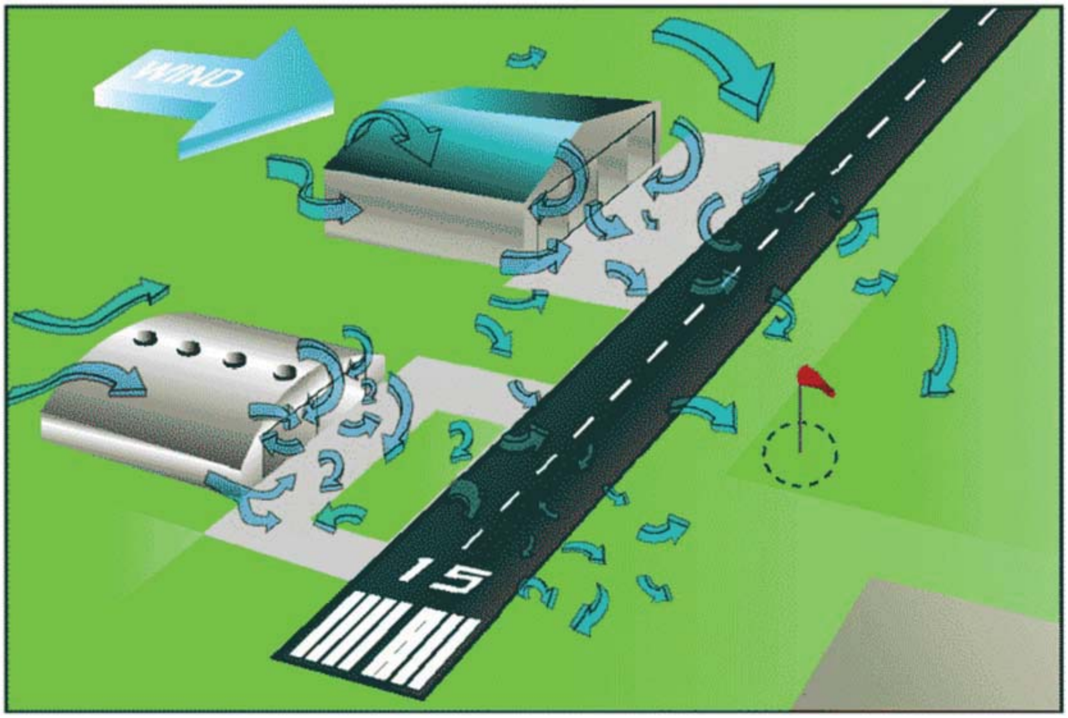

Figure 6 Mechanical Turbulence

Note. From "Aviation Weather", *Free Online Private Pilot Ground School*. Retrieved October 22, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Thermal Turbulence

Thermal turbulence is caused by the uneven heating of the ground. Certain surfaces, such as plowed fields and pavement, are heated more rapidly than others, such as grass-covered fields and water. This causes isolated convective currents that are responsible for bumpy conditions as an airplane flies in and out of them. These convective currents can have a pronounced effect of the flight path of an airplane approaching a landing area, causing it to either overshoot or undershoot.

Rising convective currents are commonly referred to as "thermals" or "lift". Glider pilots use their knowledge of the terrain to find thermals and soar for extended periods of time. They also learn to recognize and avoid sinking convective currents (commonly known as "sink").

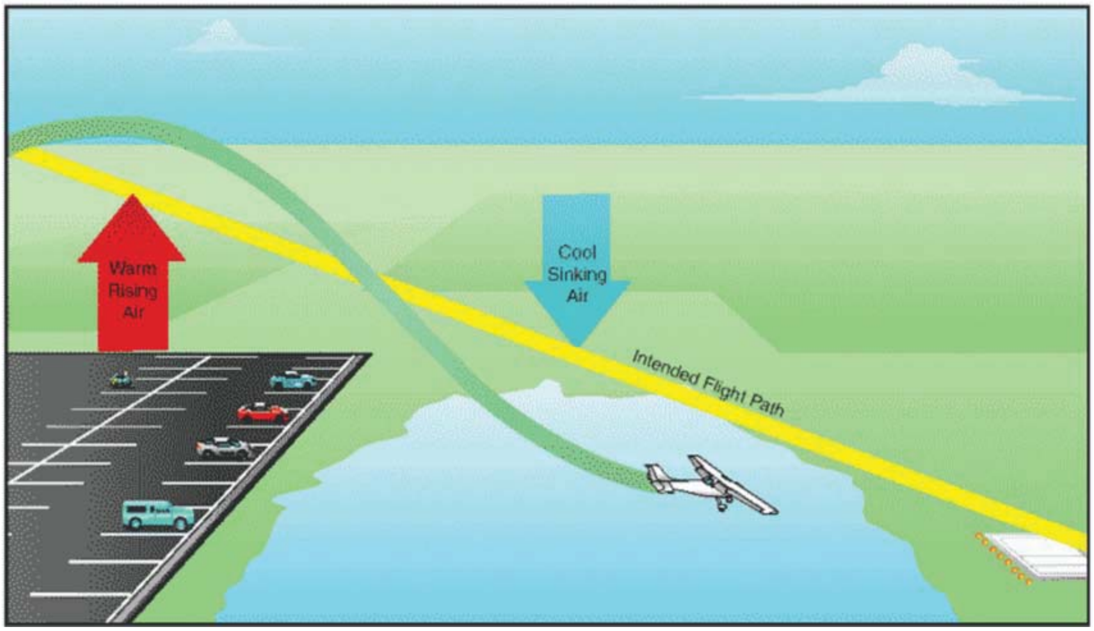

Figure 7 Thermal Turbulence

Note. From "Aviation Weather", *Free Online Private Pilot Ground School*. Retrieved October 22, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Frontal Turbulence

Frontal turbulence is caused by the lifting of warm air by the sloping frontal surface and the friction between the two opposing air masses. This turbulence is strongest in cold fronts, especially when the warm air is moist and unstable.

Wind Shear

Wind shear is caused when there are significant changes in wind speed and direction with height.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What causes mechanical turbulence?

Q2. Name two examples of terrain that heat more rapidly than water.

Q3. In which type of front is turbulence more pronounced?

ANTICIPATED ANSWERS:

A1. Mechanical turbulence is caused by friction between the air and the ground.

A2. A plowed field and pavement.

A3. Cold front.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What are the three stages of a thunderstorm?

Q2. What are the three main types of icing?

Q3. What are the four types of turbulence?

ANSWERS:

A1. Cumulus, mature, and dissipating.

A2. Clear ice, rime ice, and frost.

A3. Mechanical turbulence, thermal turbulence, frontal turbulence, and wind shear.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Severe weather conditions can adversely affect a flight and ruin a pilot's day. Knowing how to recognize and deal with these conditions is essential for future aviation training.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited

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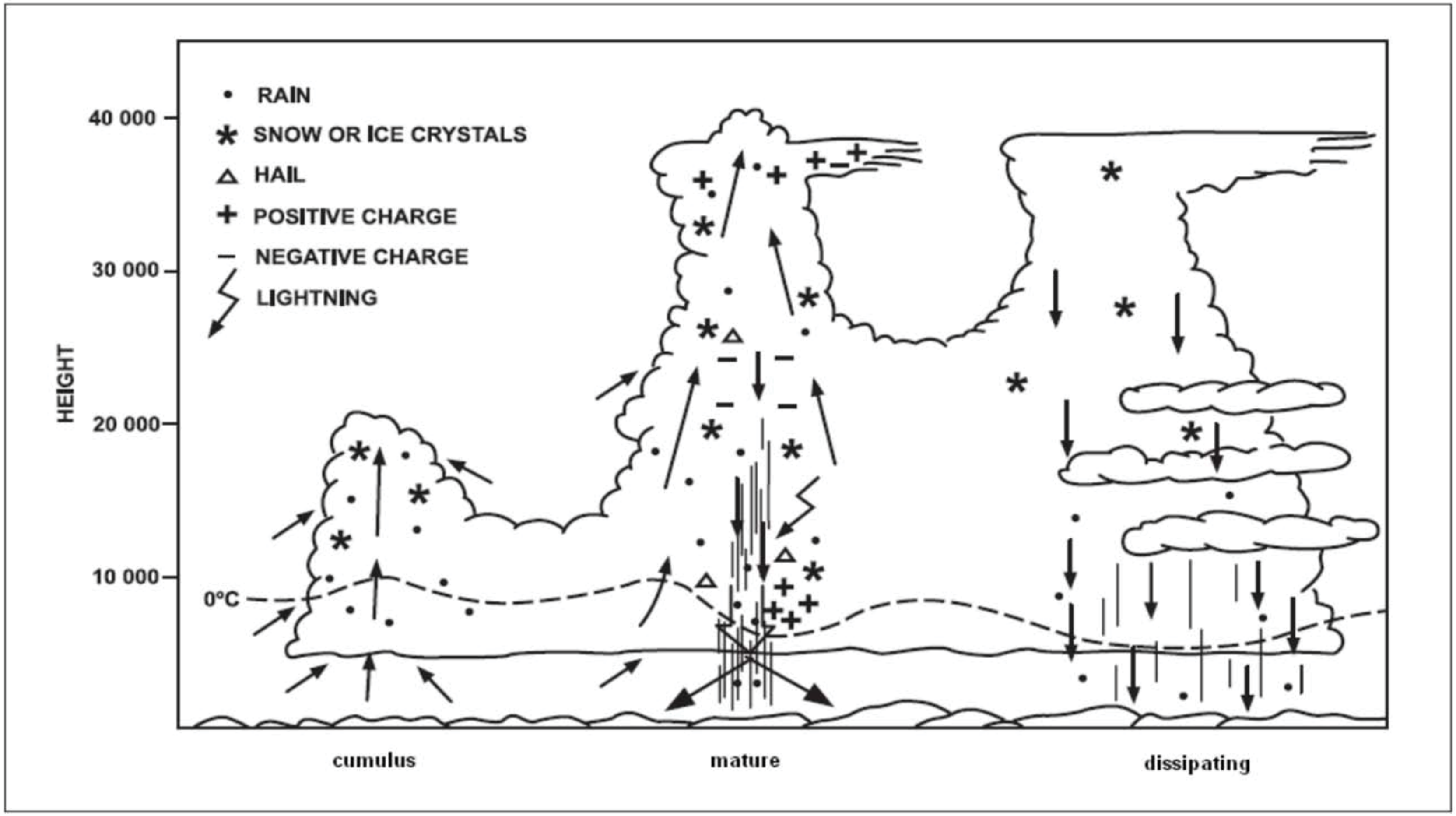

Figure A-1 Stages of a Thunderstorm

Note. From *Air Command Weather Manual* (p. 15-2), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

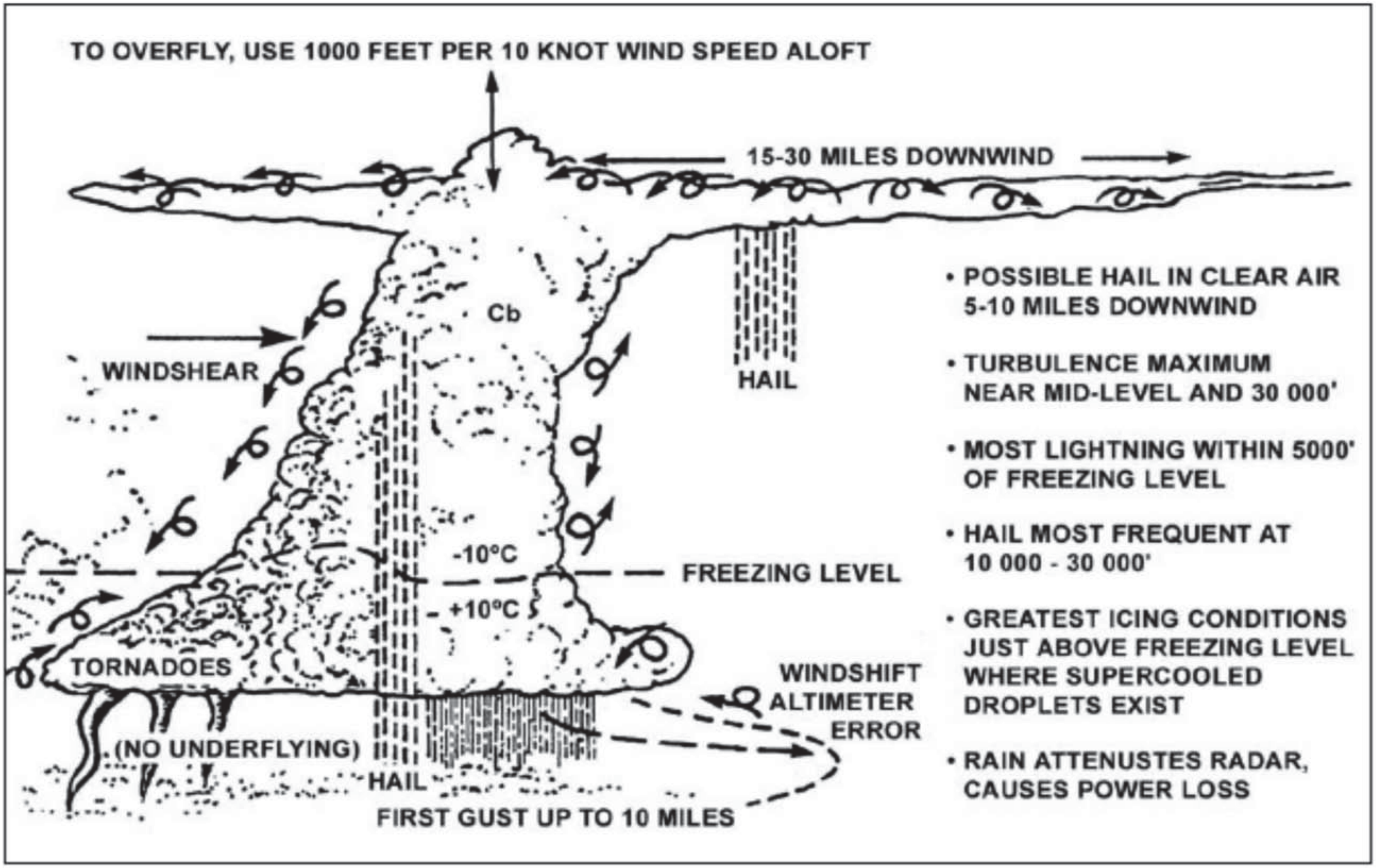

Figure A-2 Thunderstorm Dangers

Note. From *Air Command Weather Manual* (p. 15-2), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

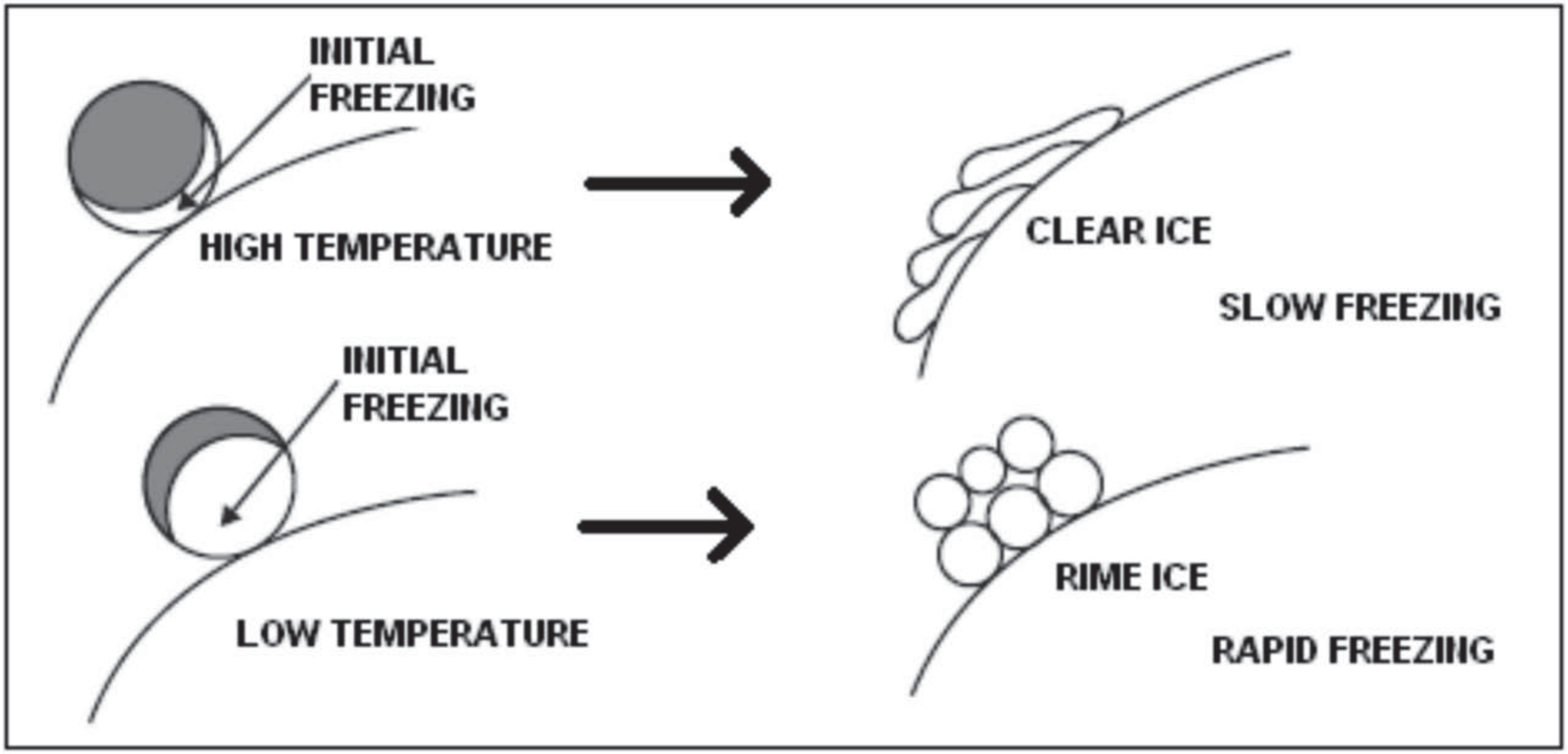

Figure A-3 Clear Ice and Rime Ice

Note. From *Air Command Weather Manual* (p. 9-4), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

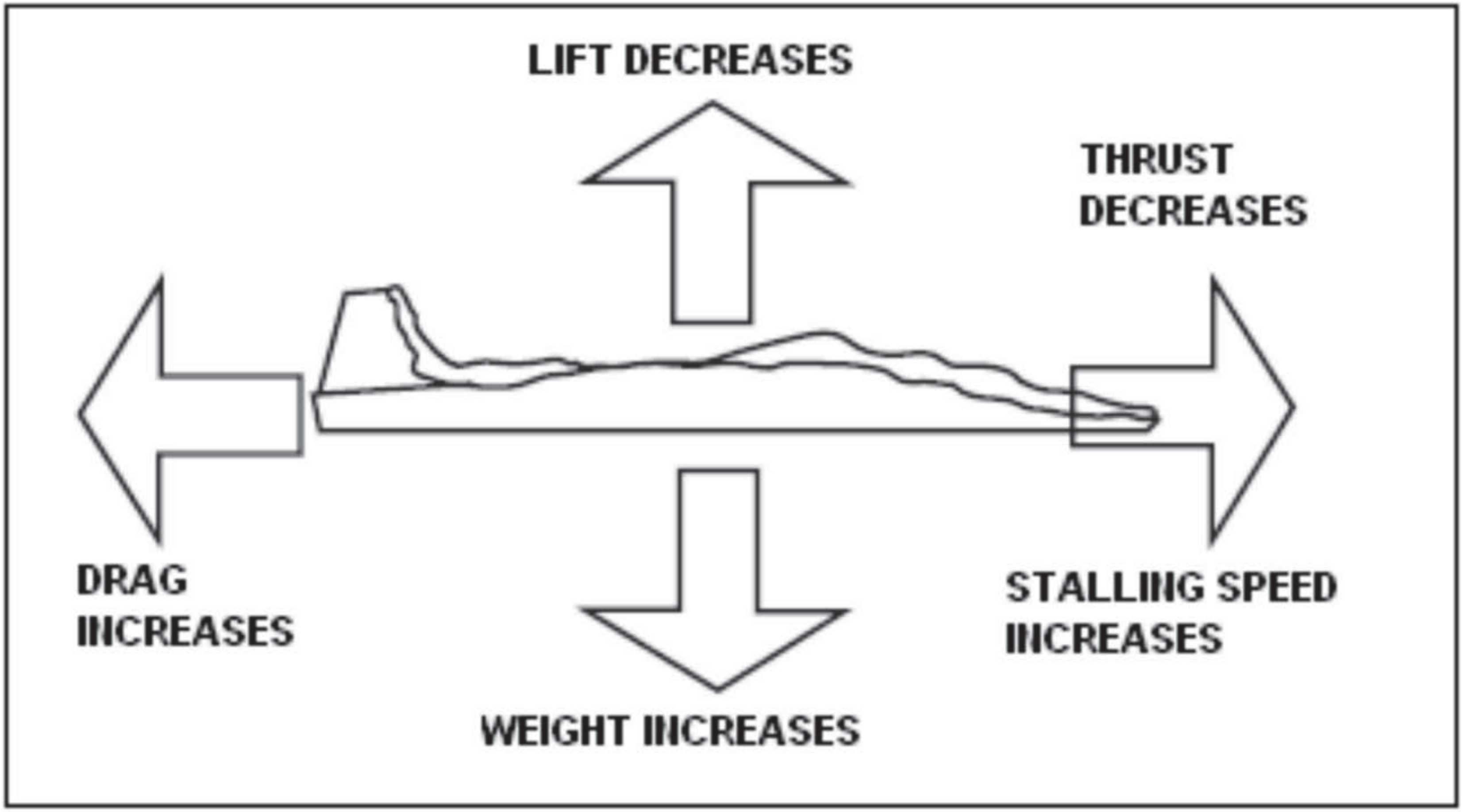

Figure A-4 Effects of Icing

Note. From *Air Command Weather Manual* (p. 9-1), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

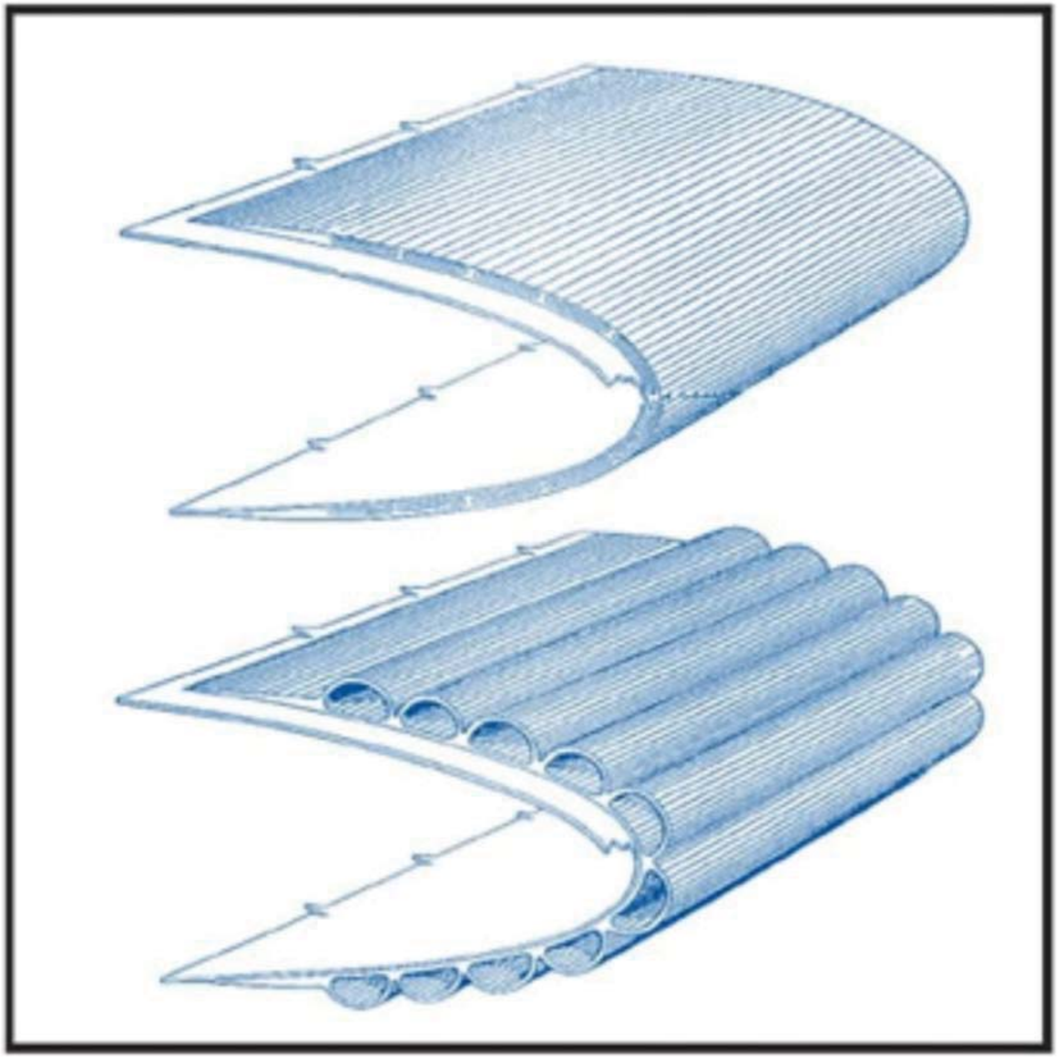

Figure A-5 Rubber Boots

Note. From "Icing Conditions in Flight", *Pilot Friend*. Retrieved October 22, 2008, from http://www.pilotfriend.com/safe/safety/icing_conditions.htm

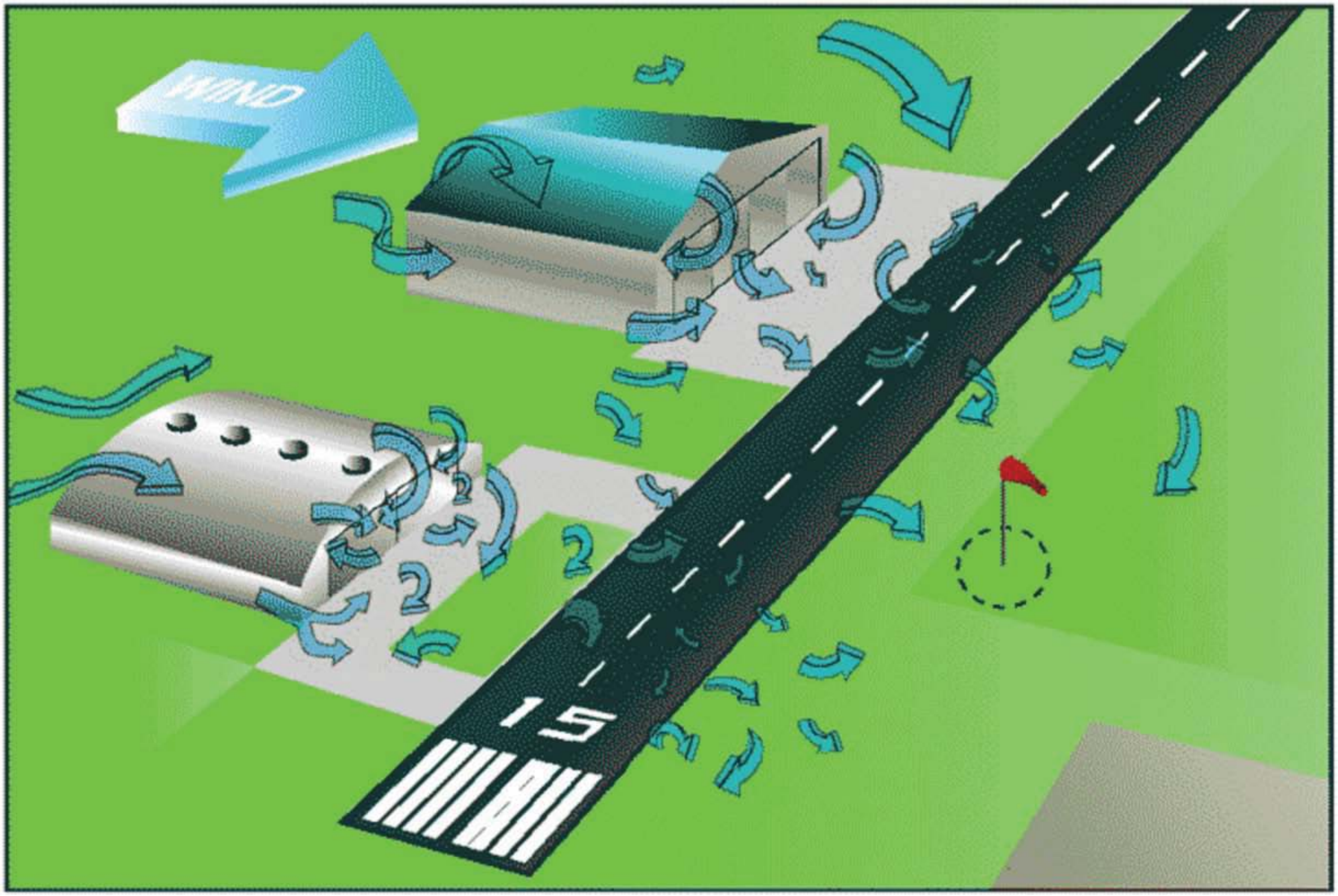

Figure A-6 Mechanical Turbulence

Note. From "Aviation Weather", *Free Online Private Pilot Ground School*. Retrieved October 22, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

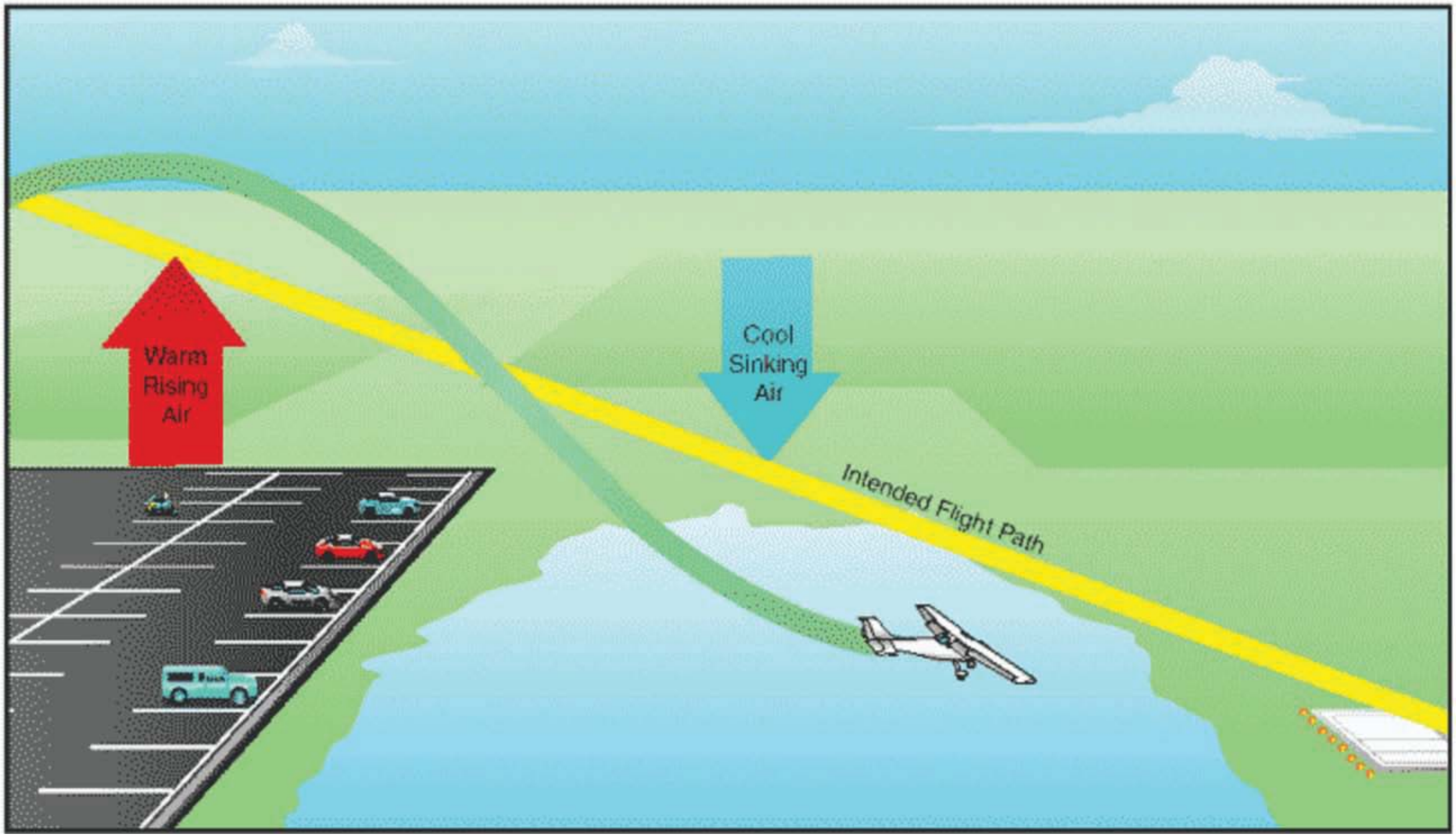

Figure A-7 Thermal Turbulence

Note. From "Aviation Weather", *Free Online Private Pilot Ground School*. Retrieved October 22, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 5

EO C436.03 – ANALYZE WEATHER INFORMATION

Total Time:	90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare the slides located at Attachments A, C–G, I and J.

Photocopy the handouts located at Attachments B and H.

Make handouts of recent METARs, TAFs, FDs and GFAs in standard format from the NAV CANADA aviation weather website for each cadet.

Make a copy in plain language of the same METARs, TAFs, FDs and GFAs handouts from the NAV CANADA aviation weather website being given to each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1–7 to introduce weather reports and forecasts, to give the cadets the basic material they need to decode and analyze the information and to generate interest in the subject.

An in-class activity was chosen for TP 8 as it is an interactive way for the cadets to practice analyzing weather information under supervision.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have analyzed weather information.

IMPORTANCE

It is important for cadets to analyze weather information as this skill is used by cadets to analyze weather when preparing for day-to-day activities and to fly. Being able to analyze weather information provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

Teaching Point 1	**Describe a METAR.**
Time: 5 min	Method: Interactive Lecture

METARs

Show the cadets the slide of Attachment A.

Definition

METAR is the name given to the international meteorological code used in aviation routine weather reports. These reports describe the existing weather conditions at a specific time and location. In other words, the METAR is a snapshot of the current weather; it is not a forecast.

Frequency of Reports

METARS are normally issued every hour, on the hour as weather does not normally change much in this brief period of time. METARs are only valid at the time that they are issued, not for the hour between reports.

Special Weather Reports (SPECI)

There are times when the weather changes drastically in a short period of time. When this happens a SPECI is issued. SPECIs use the same code as a METAR, but start with SPECI.

Where METARs are Available

METARs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What does a METAR describe?

Q2. How often are METARs normally issued?

Q3. When is a SPECI issued?

ANTICIPATED ANSWERS:

A1. A METAR describes the existing weather conditions at a specific time and location.

A2. METARS are normally issued every hour, on the hour.

A3. A SPECI is used when the weather changes drastically in a short period of time.

Teaching Point 2	**Familiarize the cadets with METAR terminology.**
Time: 15 min	Method: Interactive Lecture

TERMINOLOGY USED IN METARs

Indicate on the slide of Attachment A each of the following groupings as they are covered.

METAR is a code used in aviation weather reporting. This code is based on the World Meteorological Organization's (WMO) standards and conventions. A METAR is organized into sections with each section always in the same order.

Report Type

The report name is in the first line of the text. The name will show as either METAR or SPECI.

Location Indicator

Each weather reporting station in Canada is assigned a four-letter identifier, starting with the letter C. The second letter indicates the type of station and the last two letters identify the specific reporting station.

For example, CYOW is the reporting station at Ottawa / MacDonald-Cartier International Airport. The C means the station is Canadian, the Y means the station is co-located with an airport, and OW is the airport identifier.

Date and Time of Observation

The date and time of the observation are given as a six-digit grouping, based on Coordinated Universal Time (UTC / ZULU / Z). The first two digits signify the day of the current month, while the last four digits signify the time of the day. The official time of the observation is given for all METAR reports that do not deviate more than 10 minutes from the top of the hour. SPECIs will have the time reported to the exact minute.

For example, a METAR will show as 091000Z which means that the observation was taken on the ninth day of the month at 1000 hours UTC (or within 10 minutes of that hour).

For example, a SPECI will show as 091036Z, which means that a significant change in weather was observed on the ninth day of the month at 1036 hours UTC.

Report Modifier

This field may contain two possible codes: AUTO or CC* (where * is a letter from A–Z which represents corrections). AUTO indicates that the report is primarily based on observations from an automated weather observation station (AWOS). CC* is used to indicate corrected reports, where the first correction is CCA, the second is CCB, and so on. Both AUTO and CC* may be found in the same report.

Wind

This group reports the two-minute average wind direction and speed. Direction is always three digits, given in degrees true but rounded off to the nearest 10 degrees. Speed is normally two digits, and is given in knots (nautical miles per hour or kt). A reading of 00000KT indicates calm winds.

For example, 35016KT means winds are from 350 degrees true (rounded off) at 16 knots.

If gust conditions exist, the direction and speed will be followed by a G and the maximum gust strength. A gust must be five knots stronger than the 10-minute average wind speed.

For example, 35016G25KT means winds are from 350 degrees true at 16 knots gusting to 25 knots.

Prevailing Visibility

Prevailing visibility is the average visibility at the reporting station. The prevailing visibility is reported in statute miles (SM) or fractions of a statute mile.

For example, 3SM means the prevailing visibility is 3 statute miles.

Runway Visual Range

This is only included if the prevailing visibility is less than 1 SM, or the runway visual range is less than 6 000 feet. This group will start with an R, then the runway number (eg, 06) and position (eg, L for left, R for right, C for centre), followed by the runway visual range in hundreds of feet. This is based on a 10-minute average. The runway visual range trend is indicated if there is a distinct upward or downward trend from the first to the second five-minute part-period. If the runway visual range changes by 300 feet or more it is indicated as /U for an upward trend or /D for a downward trend. No distinct change is indicated as /N. If it is not possible to determine the trend it will be left blank.

For example, R06L/4000FT/D means the runway visual range for runway 06 left is 4 000 feet with a downward trend.

Present Weather

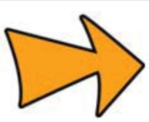
Distribute the handout of Attachment B to the cadets.

This group indicates the current weather phenomena at the reporting station. This may include precipitation, obscuration, or other phenomena.

Each phenomenon is represented by a code, which may be two to nine characters in length. Each code may include one or both of the following prefixes:

- **Intensity.** (-) indicates light, (+) indicates heavy, and no symbol indicates moderate.
- **Proximity.** Used primarily with precipitation or tornadoes. VC will precede certain phenomena, meaning that they are in the vicinity (5 SM) of the station, but not actually at the station.

For example, VCFZRABLSN+SNVA means in the vicinity of the airport there is freezing rain, blowing snow, heavy snow, and volcanic ash.



The abbreviations used for present weather are a mixture of English and French root words. FZ comes from freezing, while BR comes from brumé (mist), and FU comes from fumée (smoke).

Sky Conditions

This group reports the sky condition for layers aloft. The group will include how much of the sky is covered, measured in oktas (eighths of the sky) and the height of the clouds in hundreds of feet above ground level (AGL). The sky cover is represented by the following abbreviations:

- **SKC.** Sky clear, no cloud present.
- **FEW.** Few, greater than zero to two-eighths cloud cover.
- **SCT.** Scattered, three-eighths to four-eighths cloud cover.
- **BKN.** Broken, five-eighths to less than eight-eighths cloud cover.
- **OVC.** Overcast, eight-eighths cloud cover.
- **CLR.** Clear, clear below 10 000 feet AGL.

Cloud height is represented by a three-digit number, which when multiplied by one hundred equals the actual height AGL. There will be one entry for every layer of cloud.

For example, SCT025 means scattered cloud at 2 500 feet AGL.

Temperature and Dewpoint

This group reports the air temperature and dewpoint temperature, rounded to the nearest whole degree Celsius. A negative value will be preceded by an M. A forward slash (/) will separate the two values.

For example, M05/M08 means the temperature is minus five degrees Celsius and the dewpoint is minus eight degrees Celsius.

Altimeter Setting

This group reports the altimeter setting at the reporting station in inches of mercury. The group starts with an A followed by four digits, which directly relate to the actual value of the altimeter setting. Place a decimal after the second digit in order to read this group.

For example, A3006 means the altimeter setting is 30.06 inches of mercury.

Recent Weather

This group reports recent weather of operational significance. The group indicator RE follows without a space, by the appropriate abbreviation(s) for weather observed during the period since the last METAR or SPECI, but not observed at the time of observation.

For example, RE+PL means although not observed now, there were heavy ice pellets recently reported.

Wind Shear

This group reports low level wind shear (within 1 600 feet AGL) along the takeoff or approach path of the designated runway. The two-number runway identifier is used, to which the letters L, C, or R may be appended. If the existence of wind shear applies to all runways, WS ALL RWY is used.

Remarks

This group will usually include cloud types in each layer as well as opacity, general weather remarks, and sea level pressure measured in hectopascals (hPa). The sea level pressure will always be the last entry in a METAR, prefaced by SLP. Sea level pressure is translated by placing the decimal point between the last two digits and either adding a 9 or a 10 in front of the value given. The goal is to make the number as close to 1 000 as possible.

For example, SLP123 means sea level pressure is 1012.3 hPa.

For example, SLP998 means sea level pressure is 999.8 hPa.

SLP actually represents the station pressure or the theoretical sea level pressure at the reporting station.

The = symbol is used to indicate the end of information.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. How are date and time expressed in a METAR?

Q2. What does the present weather section indicate?

Q3. What is the last entry of a METAR?

ANTICIPATED ANSWERS:

A1. The date and time of the observation are given in a six-digit grouping, based on universal coordinated time (UTC).

A2. This section indicates the current weather phenomena at the reporting station.

A3. The sea level pressure will always be the last entry in a METAR.

Teaching Point 3	**Describe a TAF.**
Time: 5 min	Method: Interactive Lecture

TAFs

Show the cadets the slide of Attachment C.

Definition

TAF is the name given to the international meteorological code for an aerodrome forecast. These forecasts describe the expected weather conditions that will affect takeoff and landing at the aerodrome.

Issue and Validity

TAFs are prepared for approximately 180 aerodromes across Canada. They are limited to aerodromes for which METAR and SPECI reports are available. TAFs are generally prepared four times daily with periods of coverage from 12–24 hours. A TAF is valid from the time of issue until it is amended or until the next scheduled TAF is issued.

Where TAFs are Available

TAFs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What do TAFs describe?

Q2. How often are TAFs generally prepared?

Q3. Where can TAFs be found?

ANTICIPATED ANSWERS:

A1. The expected weather conditions that will affect takeoff and landing at an aerodrome.

A2. Four times daily.

A3. TAFs can be found at:

- NAV CANADA's aviation weather website,
- an FSS, or
- an FIC.

Teaching Point 4	**Familiarize the cadets with TAF terminology.**
Time: 15 min	Method: Interactive Lecture

TERMINOLOGY USED IN TAFs

Indicate on the slide of Attachment C each of the following groupings as they are covered.

Much of this information will be a brief review as TAFs are similar to METARs in many ways. The abbreviations of expected weather conditions will follow the same form and order of the METAR, and will have the same meaning.

A TAF is organized into sections with each section always in the same order.

Report Type

The code name TAF is given in the first line of text. It may be followed by “AMD” for amended or corrected forecasts.

Location Indicator

A four-letter International Civil Aviation Organization (ICAO) location indicator is used, as in the METAR.

Date and Time of Origin

As with the METAR format, the day of the month and time (UTC) of origin are included in all forecasts. TAFs are issued approximately 30 minutes before the validity period. Some forecasts have update cycles as frequent as every three hours; however, the next issue time will always be indicated in the remarks group.

Period of Validity

The period of validity for the TAF is indicated by two four-digit date / time groups. The first four-digit group indicates the start date and time of the TAF, and the second four-digit group indicates the end date and time of the TAF. The maximum validity period for a TAF is 30 hours; however, some TAFs have staggered issue times and more frequent update cycles, which will affect their periods of validity.

Wind

The forecasted wind direction and speed are encoded as in a METAR.

Low-Level Wind Shear

This group is used if the forecaster has strong evidence to expect significant, non-convective wind shear that could adversely affect aircraft operation within 1 500 feet AGL over the aerodrome. The coded grouping begins with the letters WS followed by a three-digit grouping indicating the height in hundreds of feet AGL of the shear zone. A slash followed by a five-digit group indicates the wind speed and direction at that height.

For example, WS 015/20015KT means wind shear is forecast at 1 500 feet AGL over the aerodrome. The wind will be from 200 degrees true at 15 knots.

Prevailing Visibility

The prevailing visibility is encoded as in a METAR, except that visibility greater than six statute miles will be indicated by the code P6SM.

For example, 3/4SM means the visibility is forecast to be 3/4 statute mile.

Significant Weather

Refer the cadets to the handout of Attachment B.

Significant weather is encoded with the same codes as present weather in METARs. Intensity and proximity qualifiers, descriptors, precipitation, and obscuration are included as required.

For example, -RA BR means light rain and mist.

Sky Condition

Sky condition is encoded as in a METAR. Possible codes for sky cover amounts are SKC, FEW, SCT, BKN, OVC, CLR, and VV. A vertical visibility (VV) is reported in hundreds of feet when the sky is obscured. Forecast cloud type is not identified except in the case of cumulonimbus layers.

For example, BKN040CB means broken cumulonimbus cloud at 4 000 feet.

Change Groups

There are four change groups:

- FM (from),
- BECMG (becoming),
- TEMPO (temporarily), and
- PROB (probability).

FM. Indicates the weather is forecast to change permanently and rapidly. All forecast conditions given before this group are superseded by the conditions indicated after the group. In other words, a complete forecast will follow and all elements must be indicated, including those for which no change is forecast. The time group represents hours and minutes in UTC.

For example, FM280945 means from the 28th day of the month at 0945Z.

BECMG. Used when a permanent change in a few weather elements is forecast to occur gradually, with conditions evolving over a period of time (normally one to two hours, but not more than four hours). Normally only those elements for which a change is forecast to occur will follow BECMG. Any forecast weather element not indicated as part of the BECMG group remains the same as the period prior to the change.

The start and stop time of the change period is indicated by two four-digit date / time groups following BECMG. The first two digits of each group indicate the date, while the last two digits of each group indicate the time in whole UTC hours.

For example, BECMG 2808/2809 OVC030 means a change towards overcast sky conditions at 3 000 ft AGL occurring gradually between 0800Z and 0900Z on the 28th day of the month.

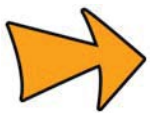
TEMPO. Used when a temporary fluctuation in some or all of the weather elements is forecast to occur during a specified period. When an element is not indicated after TEMPO, it is the same as the period prior to the change. The time period is indicated the same as with BECMG.

For example, TEMPO 2812/2815 1SM RA BR means temporarily between 1200Z and 1500Z on the 28th day of the month, visibility is forecast to be one statute mile with rain and mist.

If a significant change in weather or visibility is forecast, all weather groups are indicated following BECMG or TEMPO, including those that are unchanged. When the ending of significant weather is forecast, the abbreviation NSW (no significant weather) is used.

PROB. Used to indicate a 30 or 40 percent probability of changing conditions that would constitute a hazard to aviation, such as thunderstorms, freezing precipitation, and low-level wind shear. The time period is indicated the same as with BECMG and TEMPO.

For example, PROB30 2817/2821 1/2SM +TSRAGR means there is a 30 percent probability between 1700Z and 2100Z on the 28th day of the month that visibility will be 1/2 statute mile with heavy thunderstorms, rain, and hail.



A probability of less than 30 percent is not considered to justify the use of the PROB group. When the probability is 50 percent or more, this shall be indicated by the use of BECMG, TEMPO, or FM, as appropriate.

Remarks

Remarks will be prefaced by the abbreviation RMK. Remarks may include such information as when a TAF is based on observations taken by an Automated Weather Observation System (AWOS), and when there are significant discrepancies between the AWOS and a TAF. Remarks will indicate the issue date and time (UTC) of the next regular TAF.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS:

Q1. What abbreviation will be used when the ending of significant weather is forecast?

Q2. What does the change group FM indicate?

Q3. In which section will the issue time for the next TAF be indicated?

ANTICIPATED ANSWERS:

A1. NSW.

A2. FM indicates the weather is forecast to change permanently and rapidly.

A3. The remarks section.

Teaching Point 5	**Describe an FD.**
Time: 5 min	Method: Interactive Lecture

FDs

Show the cadets the slide of Attachment D.

Definition

An FD is an forecast of upper wind conditions and temperatures at selected levels. Wind direction is given in degrees true to the nearest ten degrees and wind speed is in knots.

Decoding

Temperatures are not forecast for 3 000 feet; in addition, this level is omitted if the terrain elevation is greater than 1 500 feet. All forecast temperatures for altitudes over 24 000 feet are negative.

When the forecast speed is less than five knots, the code group is 9900, which reads light and variable. Encoded wind speeds from 100–199 knots have 50 added to the direction code and 100 subtracted from the speed. Wind speeds that have had 50 added to the direction can be recognized when figures from 51–86 appear in the code. Since no such directions exist (eg, 510 degrees to 860 degrees), obviously they represent directions from 010 degrees to 360 degrees. Should the forecast wind speed be 200 knots or greater, the wind group is coded as 199 knots. For example, 7799 is decoded as 270 degrees at 199 knots or greater.

Show the cadets the slide of Attachment E.

Examples of decoding FD winds and temperatures are as follows (the third and fourth examples are for altitudes above 24 000 feet):

EXAMPLE	DECODED
9900+00	Wind light and variable. Temperature zero degrees Celsius.
2523	Wind 250 degrees true at 23 knots.
791159	Wind 290 degrees true (79 - 50 = 29) at 111 knots (11 + 100 = 111). Temperature minus 59 degrees Celsius.
859950	Wind 350 degrees true (85 - 50 = 35) at 199 knots or greater, temperature minus 50 degrees Celsius.

Figure 1 FD Decoding

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

Where FDs are Available

FDs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 5

QUESTIONS:

Q1. What is an FD?

Q2. At which level are temperatures not forecast?

Q3. What does the code group 9900 mean?

ANTICIPATED ANSWERS:

A1. An FD is a forecast of upper wind conditions and temperatures at selected levels.

A2. 3 000 feet.

A3. Winds are light and variable.

Teaching Point 6	**Describe a GFA.**
Time: 10 min	Method: Interactive Lecture

GFAs

> Show the cadets the slide of Attachment F.

Definition

A GFA consists of a series of weather charts, each depicting the most probable meteorological conditions expected to occur below 24 000 feet, over a given area at a specified time.

Issue and Validity

GFA charts are issued four times daily, approximately 30 minutes before the beginning of the forecast period. GFAs are issued at approximately 2330, 0530, 1130, and 1730 UTC and are valid at 0000, 0600, 1200, and 1800 UTC respectively.

> Each issue of the GFA is a collection of six charts; two charts valid at the beginning of the forecast period, two charts valid six hours into the forecast period and the final two charts valid twelve hours into the forecast period. Of the two charts valid at each of the three forecast periods, one chart depicts clouds and weather while the other chart depicts icing, turbulence, and freezing level. The cadets will learn to read only the GFA Clouds and Weather Chart.

Coverage Area

Show the cadets the slide of Attachment G.

There are seven distinct GFA areas covering the entire Canadian Domestic Airspace.

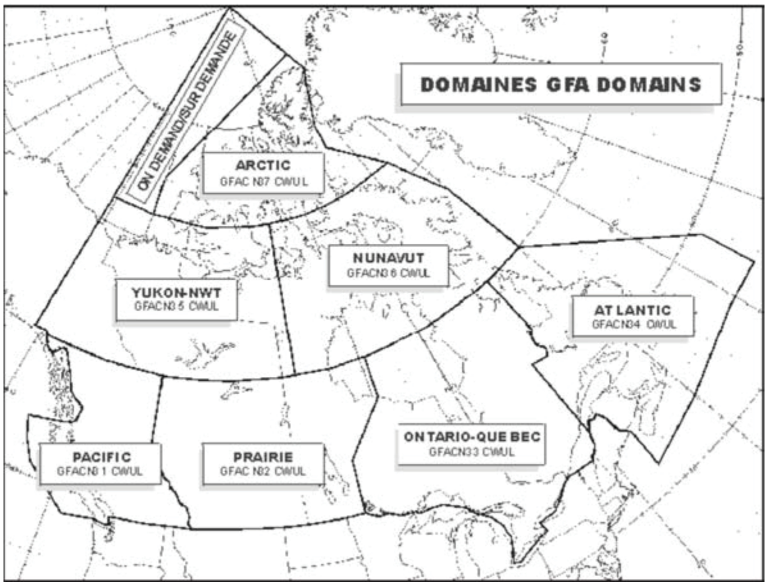


Figure 2   GFA Domains

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

Units of Measure

Speeds in a GFA are expressed in knots (kt). Horizontal visibility is measured in statute miles (SM). Times are stated in Co-ordinated Universal Time (UTC). A nautical-mile (NM) scale bar is included to assist in determining approximate distances on the chart. All heights are measured in hundreds of feet above sea level (ASL) unless otherwise noted.

Abbreviations and Symbols

Distribute the handout of Attachment H to the cadets. Show the cadets the slide of Attachment I.

Only standard meteorological abbreviations are used in a GFA. Figure 3 is a list of common weather symbols that may be found in a GFA.

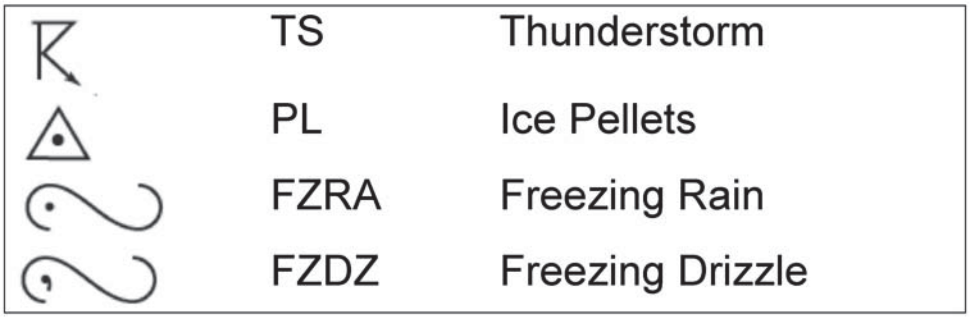


Figure 3 Weather Symbols

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

Where GFAs are Available

GFAs can be found at several locations. The three most common locations are:

- NAV CANADA's aviation weather website,
- a Flight Services Station (FSS), and
- a Flight Information Centre (FIC) (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 6

QUESTIONS:

Q1. How often are GFAs issued?

Q2. How are heights measured in GFAs unless otherwise noted?

Q3. How many distinct GFA coverage areas are there in Canada?

ANTICIPATED ANSWERS:

A1. Four times daily.

A2. In hundreds of feet above sea level (ASL).

A3. Seven.

Teaching Point 7 **Familiarize the cadets with GFA Clouds and Weather Chart layout.**

Time: 15 min Method: Interactive Lecture

GFA CLOUDS AND WEATHER CHART LAYOUT

Indicate on the slide of Attachment F each of the following groupings as they are covered.

Each GFA chart is divided into four parts: title box, legend box, comments box, and weather information section.

Figure 4 GFA Chart Layout

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

Title Box

The title box includes the chart name, issuing office four-letter identification, name of the GFA region, chart type, the date and time of issue, and the validity period.

Legend Box

The legend box includes weather symbols that may be used in the weather information part of the GFA chart. It also includes a nautical-mile scale bar to facilitate determining distances.

Comments Box

The comments box provides information that the weather forecaster considers important (eg, formation or dissipation of fog, increasing or decreasing visibility). It is also used to describe elements that are difficult to render pictorially or, if added to the depiction, would cause the chart to become cluttered (eg, light icing). The following standard phrases are also included in the comments box:

- HGTS ASL UNLESS NOTED,
- CB TCU AND ACC IMPLY SIG TURB AND ICG, and
- CB IMPLIES LLWS.

The comments box of the 12-hour GFA Clouds and Weather Chart also includes an Instrument Flight Rules (IFR) outlook for an additional 12-hour period in the lower section of the box. The IFR outlook is always general in nature, indicating the main areas where IFR weather is expected, the cause for the IFR weather, and any associated weather hazards.

Weather Information Section

The weather information section of the chart depicts a forecast of the clouds and weather conditions.

Show the slide of figures located at Attachment J as they are covered.

Synoptic features. The motion of synoptic features, when the speed of movement is forecast to be five knots or more, will be indicated by an arrow and a speed value. For speeds less than five knots, the letters QS (quasi-stationary) are used.

For example, a low pressure centre moving eastwards at 15 knots with an associated cold front moving southeast at 10 knots would be indicated as follows:

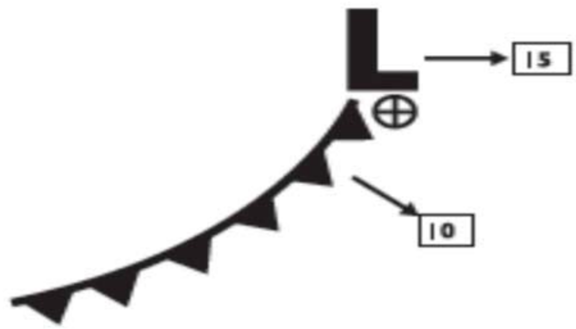


Figure 5 Synoptic Features

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

Clouds. The bases and tops of forecast clouds between the surface and 24 000 feet ASL will be indicated. The tops of convective clouds (eg, TCU, ACC, CB) are indicated, even if they extend above 24 000 feet ASL. Cirrus clouds are not depicted on the chart. The cloud type will be indicated if considered significant, however, convective clouds such as CU, TCU, ACC, and CB will always be stated when forecast to be present.

A scalloped border encloses organized areas of clouds where the sky condition is either broken (BKN) or overcast (OVC).

For example, an organized area of broken cumulus clouds based at 2 000 feet ASL with tops at 8 000 feet ASL would be indicated as follows:

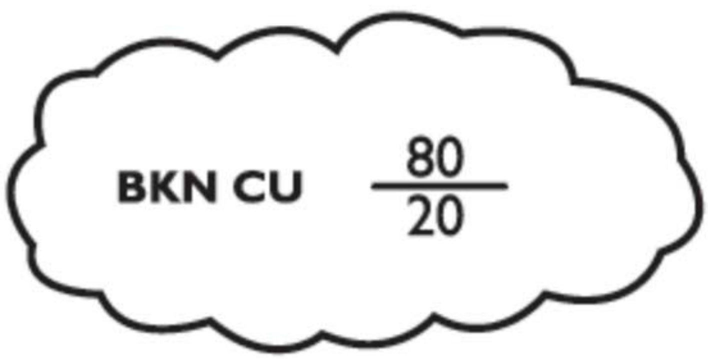


Figure 6 Broken Cumulus Clouds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 28, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

In areas where organized clouds are not forecast and the visibility is expected to be greater than six statute miles a scalloped border is not used.

For example, unorganized scattered clouds based at 3 000 feet ASL with tops at 5 000 feet ASL would be indicated as follows:

$$\text{SCT}\ \frac{50}{30}$$

Figure 7 Scattered Clouds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 28, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

When multiple cloud layers are forecast, the bases and tops of each layer are indicated.

For example, a scattered layer of cumulus cloud based at 3 000 feet ASL with tops at 5 000 feet ASL and a higher overcast layer of altostratus cloud based at 10 000 feet ASL with tops at 13 000 feet ASL would be indicated as follows:

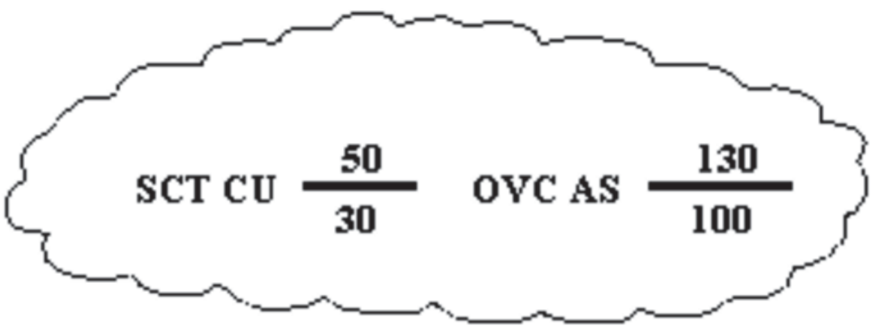


Figure 8 Multiple Cloud Layers

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 28, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

Surface-based layers. The abbreviation OBSCD (obscured) is used to describe surface-based layers. The vertical visibility in surface-based layers is measured in hundreds of feet AGL.

For example, local obscured ceilings with a vertical visibility between 300 and 500 feet AGL would be indicated as: LCL OBSCD CIG 3 - 5 AGL.

Visibility. The forecast visibility is measured in statute miles. When the visibility is expected to be greater than six statute miles, it is indicated as P6SM.

For example, a forecast visibility that is expected to vary between two and four statute miles with light rain showers would be indicated as: 2 - 4 SM - SHRA.

Weather and obstructions to vision. Forecast weather is always included immediately after the visibility. Obstructions to vision are only mentioned when the visibility is forecast to be six statute miles or less (eg, 2 - 4SM - RA BR). Areas of showery or intermittent precipitation are shown as hatched areas enclosed by a dashed green line. Areas of continuous precipitation are shown as stippled areas enclosed by a solid green line. Areas of obstruction to vision not associated with precipitation, where visibility is six statute miles or less, are enclosed by a dashed orange line. Areas of freezing precipitation are depicted in red and enclosed by a solid red line.

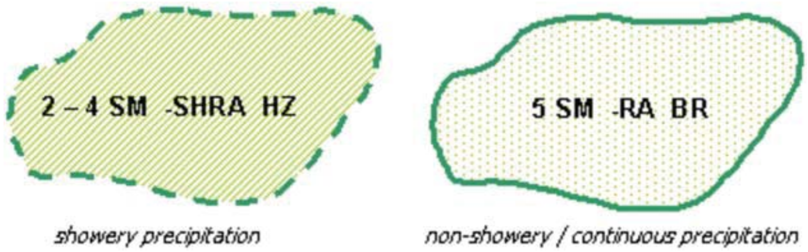


Figure 9 Weather and Obstructions to Vision

Note. From Nav Canada, 2007, *Aviation Weather Website*. Retrieved October 28, 2008, from http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=info-gfa&NoSession=NS_Inconnu&TypeDoc=gfa&Langue=anglais#abbr_symb

Isobars. Lines joining points of equal surface pressure. They are included in the GFA Clouds and Weather Chart at four-millibar intervals.

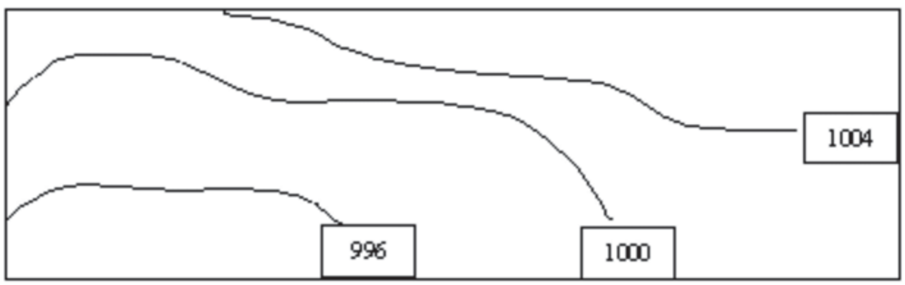


Figure 10 Isobars

Note. From Nav Canada, 2007, *Aviation Weather Website*. Retrieved October 28, 2008, from http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=info-gfa&NoSession=NS_Inconnu&TypeDoc=gfa&Langue=anglais#abbr_symb

Surface winds. The speed and direction of forecast surface winds with a sustained speed of at least 20 knots are indicated by wind barbs and an associated wind speed value. Wind gusts are indicated by the letter G, followed by the peak gust speed in knots.

For example, surface winds forecast to be from the west (270 degrees true) with a speed of 25 knots and a peak gust speed of 35 knots would be indicated as:

Figure 11 Surface Winds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 28, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

CONFIRMATION OF TEACHING POINT 7

QUESTIONS:

Q1. In which section of a GFA Clouds and Weather Chart would an IFR outlook be found?

Q2. How are areas of showery or intermittent precipitation shown?

Q3. How are organized areas of clouds where the sky condition is either broken or overcast shown?

ANTICIPATED ANSWERS:

A1. Comments box.

A2. As hatched areas enclosed by a dashed green line.

A3. Enclosed by a scalloped border.

Teaching Point 8	**Conduct an activity to have the cadets read METARs, TAFs, FDs and GFA Clouds and Weather Charts.**
Time: 15 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets read METARs, TAFs, FDs and GFA Clouds and Weather Charts.

RESOURCES

- Handouts of two or three copies of METARs, TAFs, FDs and GFA Clouds and Weather Charts in standard format,
- Copies of the same METARs, TAFs, FDs and GFA Clouds and Weather Charts in plain language format for review, and
- Abbreviations handout located at Attachment H.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Divide the cadets into pairs.
2. Distribute the handouts of METARs, TAFs, FDs and GFA Clouds and Weather Charts in standard format among the pairs.
3. Show the cadets a sample METAR, TAF, FD and GFA Clouds and Weather Chart and demonstrate reading it.
4. Indicate a section of a METAR, TAF, FD and GFA Cloud and Weather Chart and have the cadets read it.

5. Display the copies of the same METARs, TAFs, FDs and GFA Clouds and Weather Charts in plain language format to correct the cadets' work.

6. Repeat Steps 3–5 as time permits.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 8

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' participation in the activity will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Weather is a major factor in aviation. Pilots must constantly watch the weather around them as it will affect the operation and navigation of an aircraft. In particular, pilots must analyze weather information prior to flying to decide whether it is safe to fly.

INSTRUCTOR NOTES / REMARKS

Recent METARs, TAFs, FDs, and GFAs can be found at http://www.flightplanning.navcanada.ca. Click on the METAR / TAF, UPR WNDS (FDs), or Graphical FA icon and choose the desired region. METARs, TAFs, FDs, and GFAs can be printed in standard and plain language format.

It is recommended that the three periods required for this EO be scheduled consecutively.

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C2-044 *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved September 29, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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SAMPLE METARs AND SPECIs

METAR CYHZ 111700Z 28009G16KT 15SM FEW250 00/M11 A2990 RMK CS0 SLP134=

METAR CYHZ 111800Z 29015KT 15SM FEW250 01/M10 A2989 RMK CI0 SLP128=

METAR CYHZ 111900Z 30008KT 15SM FEW250 02/M12 A2987 RMK CI0 SLP123=

SPECI CYYJ 111744Z CCA 23019G24KT 20SM -SHRA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

SPECI CYYJ 111744Z 23019G24KT 20SM -RA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

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WORLD METEOROLOGICAL ORGANIZATION CODE FOR PRESENT WEATHER

QUALIFIER					WEATHER PHENOMENA			
INTENSITY or PROXIMITY 1	DESCRIPTOR 2		PRECIPITATION 3		OBSCURATION 4		OTHER 5	
Note: Precipitation intensity refers to all forms combined.	**MI**	Shallow	**DZ**	Drizzle	**BR**	Mist (Vis ≥ 5/8 SM)	**PO**	Dust/ Sand Whirls (Dust Devils)
	BC	Patches	**RA**	Rain	**FG**	Fog (Vis < 5/8 SM)	**SQ**	Squalls
	PR	Partial	**SN**	Snow	**FU**	Smoke (Vis ≤ 6 SM)	**+FC**	Tornado or Waterspout
	DR	Drifting	**SG**	Snow Grains				
- Light	**BL**	Blowing	**IC**	Ice Crystals (Vis ð 6 SM)	**DU**	Dust (Vis ≤ 6 SM)	**FC**	Funnel Cloud
	SH	Shower(s)						
Moderate (no qualifier)	**TS**	Thunderstorm	**PL**	Ice Pellets	**SA**	Sand (Vis ≤ 6 SM)	**SS**	Sandstorm (Vis < 5/8 SM) (+SS Vis < 516 SM)
			GR	Hail				
+ Heavy	**FZ**	Freezing	**GS**	Snow Pellets	**HZ**	Haze (Vis ≤ 6 SM)	**DS**	Dust storm (Vis < 5/8 SM) (+DS Vis < 516 SM)
VC In the vicinity			**UP**	Unknown precipitation (AWOS only)	**VA**	Volcanic Ash (with any visibility)		

Figure B-1 World Meteorological Organization Code for Present Weather

Note. From *Aeronautical Information Manual* (p. 145), by Transport Canada, 2008, Ottawa, ON: Transport Canada. Copyright 2007 by Her Majesty the Queen in Right of Canada.

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SAMPLE TAFs

TAF CYHZ 201738Z 2018/2118 25008KT P6SM OVC015
TEMPO 2018/2020 OVC025
FM202000 24010KT P6SM OVC025 TEMPO 2020/2022 OVC020
FM202200 23012KT P6SM BKN030
FM210200 23010KT P6SM SCT030
RMK NXT FCST BY 202100Z=

TAF CYVR 201739Z 2018/2124 10012G22KT P6SM -RA SCT025
OVC050 TEMPO 2021/2103 5SM -RA BR BKN020
BECMG 2021/2022 14012G22KT
BECMG 2101/2102 28020G30KT
FM210300 28020G30KT P6SM FEW030 SCT060
BECMG 2103/2104 26012KT
FM210800 11005KT P6SM -SHRA BKN030
BECMG 2110/2112 14010G20KT
FM211600 12012G22KT 5SM -RA BR SCT008 BKN012
RMK NXT FCST BY 202100Z=

TAF CYYG 201738Z 2018/2106 25012KT P6SM FEW009 OVC015
TEMPO 2018/2020 6SM -SHSN BKN009
FM202300 24012KT P6SM BKN025 TEMPO 2023/2102 BKN020
FM210200 26008KT P6SM SCT025 TEMPO 2102/2106 BKN025
RMK NXT FCST BY 210000Z=

TAF CYOW 201738Z 2018/2118 34012KT P6SM BKN040
FM202200 31005KT P6SM FEW050 SCT100
FM211600 31012KT P6SM BKN030
RMK NXT FCST BY 202100Z=

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SAMPLE FDS

STN YNA - NATASHQUAN. QUEBEC	**for use**	**3000**	**6000**	**9000**	**12000**	**18000**
FDCN01 CWAO FCST BASED ON 271200 DATA **VALID 271800**	**17-21**	2130	2129+05	2131+03	2140-03	2158-11
FDCN02 CWAO FCST BASED ON 271200 DATA **VALID 280000**	**21-06**	1916	1917+06	2023+03	2130-02	2152-11
FDCN03 CWAO FCST BASED ON 271200 DATA **VALID 281200**	**06-17**	1635	1633+05	1929+03	1936+00	1838-11

STN YQI - YARMOUTH. NS	**for use**	**3000**	**6000**	**9000**	**12000**	**18000**
FDCN01 CWAO FCST BASED ON 271200 DATA **VALID 271800**	**17-21**	1616	1919+10	1936+05	1934+00	2043-10
FDCN02 CWAO FCST BASED ON 271200 DATA **VALID 280000**	**21-06**	1842	1843+11	1843+06	1842+00	1842-10
FDCN03 CWAO FCST BASED ON 271200 DATA **VALID 281200**	**06-17**	1451	1551+10	1537+04	1651+00	1865-08

STN YQI - YARMOUTH. NS	**for use**	**24000**	**30000**	**34000**	**39000**	**45000**	**53000**
FDCN01 KWBC DATA BASED ON 271200Z **VALID 271800Z**	**1700-2100Z.**	2145-24	225139	225248	206558	215363	213964
FDCN02 KWBC DATA BASED ON 271200Z **VALID 280000Z**	**2100-0600Z.**	2043-23	215140	215149	214558	215062	213864
FDCN03 KWBC DATA BASED ON 271200Z **VALID 281200Z**	**0600-1700Z.**	1855-23	195738	205047	226656	216062	204264

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Decoding FDs

EXAMPLE	DECODED
9900+00	Wind light and variable, temperature zero degrees Celsius.
2523	Wind 250 degrees true at 23 knots.
791159	Wind 290 degrees true (79 - 50 = 29) at 111 knots (11+ 100 = 111), temperature -59 degrees Celsius.
859950	Wind 350 degrees true (85 - 50 = 35) at 199 knots or greater, temperature -50 degrees Celsius.

Figure E-1 FD Decoding

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

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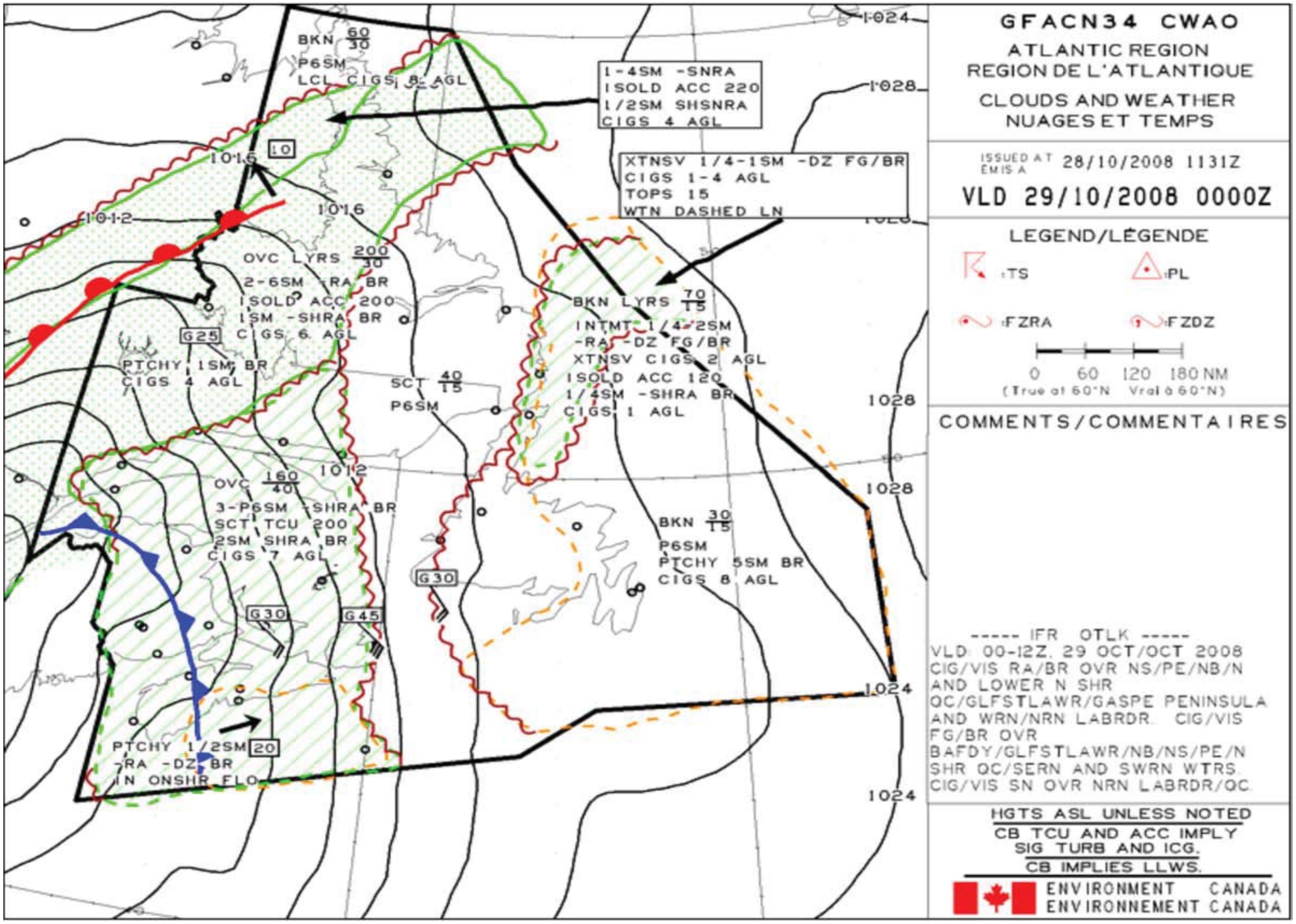

Figure F-1 GFA Clouds and Weather Chart

Note. From Nav Canada, 2007, *Aviation Weather Website*. Retrieved October 28, 2008, from http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Langue=anglais&NoSession=NS_Inconnu&Page=forecast-observation&TypeDoc=html

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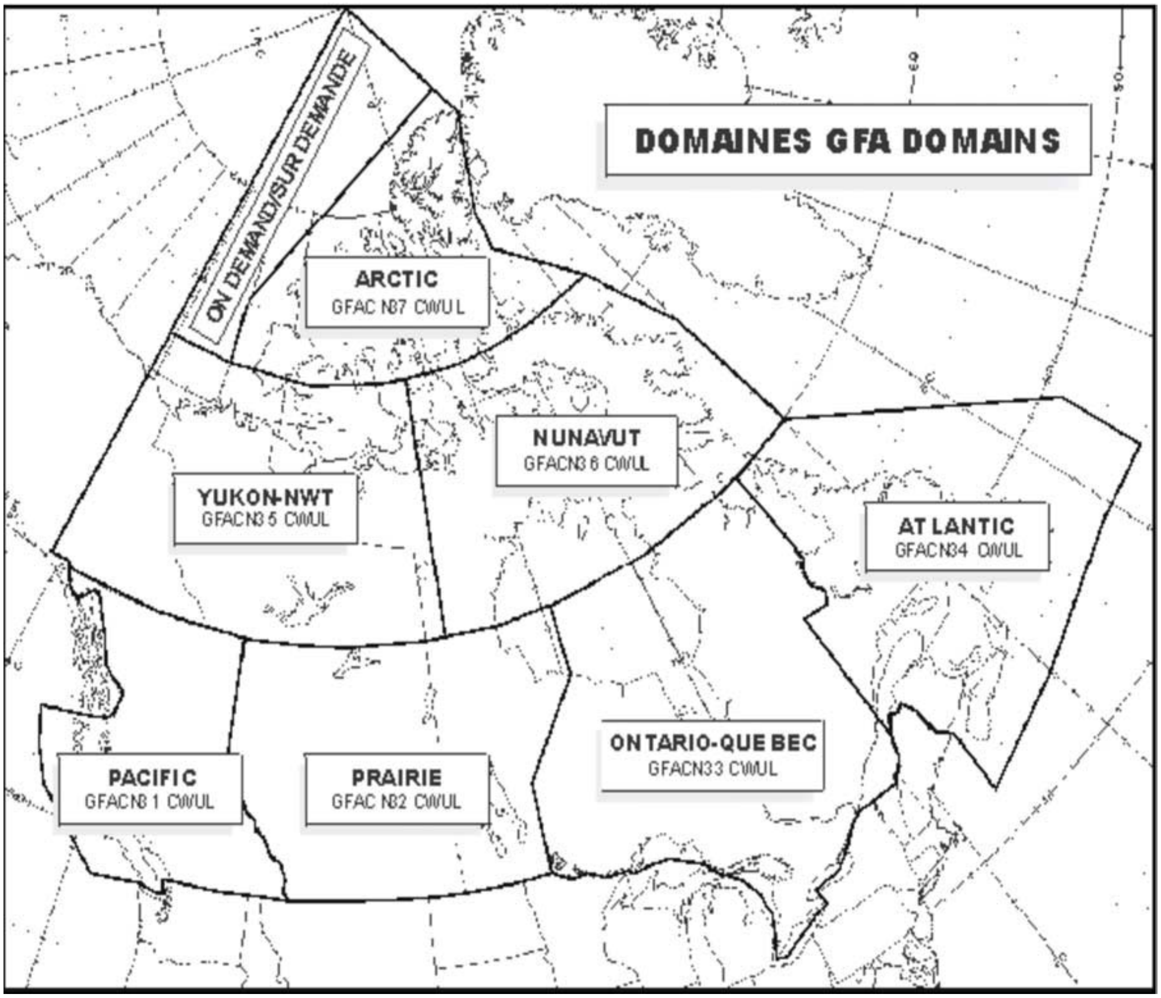

Figure G-1 GFA Domains

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

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3.6 Abbreviations – Aviation Forecasts

CONTRACTION	PLAIN LANGUAGE
ABV	above
ACCAS	altocumulus castellanus
ACRS	across
ACSL	standing lenticular altocumulus
ACT	active
AFT	after
AFL	above freezing layer
AHD	ahead
ALF	aloft
ALG	along
ALT	altitude
AIRMS	air mass
APCH	approach
APCHG	approaching
ASL	above sea level
AWOS	Automated Weather Observation System
BECMG	becoming
BFR	before
BGN	begin
BGNG	beginning
BHND	behind
BKN	broken
BL	blowing
BLDG	building
BLO	below
BLZD	blizzard
BDRY	boundary
BR	mist
BRF	brief
BRFLY	briefly
BRKS	breaks
BTN	between
CAT	clear air turbulence
CAVOK	ceiling and visibility OK
CB	cumulonimbus
CIG	ceiling
CLD	cloud
CLR	clear

CONTRACTION	PLAIN LANGUAGE
CLRG	clearing
CNTR	centre
CNTRD	centred
CONDS	conditions
COTRAILS	condensation trails
CONTUS	continuous
CONTG	continuing
CST	coast
CU	cumulus
DCRG	decreasing
DEG	degree
DFUS	diffuse
DIST	distant
DNS	dense
DNSLP	downslope
DP	deep
DPNG	deepening
DRFTG	drifting
DURG	during
DVLPG	developing
DZ	drizzle
E	east
ELSW	elsewhere
ELY	easterly
EMBD	embed
ENDG	ending
ENTR	entire
FCST	forecast
FEW	few clouds
FG	fog
FILG	filling
FLWD	followed
FLWG	following
FM	from
FNT	front
FRQ	frequent
FZLVL	freezing level
FROIN	frost on indicator
FROPA	frontal passage
FRQ	frequent

Figure H-1 Abbreviations

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

CONTRACTION	PLAIN LANGUAGE
FT	feet, foot
FU	smoke
FZ	freezing
GND	ground
GRAD	gradient
GRDLY	gradually
HGT	height
HI	high
HLTP	hilltop
HND	hundred
HR	hour
HVY	heavy
ICG	icing
ICGIC	icing in cloud
ICGIP	icing in precipitation
IMDTLY	immediately
INCRG	increasing
INDEF	indefinite
INSTBY	instability
INTMT	intermittent
INTS	intense
INTSFY	intensify
ISLD	island
ISOL	isolate(d)
KT	knot(s)
LCL	local
LFTG	lifting
LGT	light
LIFR	low IFR
LK	lake
LLJ	low level jet stream
LLWS	low level wind shear
LN	line
LO	low
LTL	little
LVL	level
LWIS	limited weather information system
LWR	lower
LWRG	lowering
LYR	layer

CONTRACTION	PLAIN LANGUAGE
MDFYD	modified
MDT	moderate
MI	shallow
MID	middle
MOVG	moving
MPH	miles per hour
MRNG	morning
MRTM	maritime
MSTR	moisture
MTS	mountains
MVFR	marginal VFR
MXD	mixed
MXG	mixing
N	north
NE	northeast
NELY	northeasterly
NGT	night
NLY	northerly
NM	nautical mile(s)
NMRS	numerous
NR	near
NRLY	nearly
NSW	no significant weather
NW	northwest
NWLY	northwesterly
OBSC	obscure(d)
OCLD	occlude
OCLDG	occluding
OCLN	occlusion
OCNL	occasional
OCNLY	occasionally
OFSHR	offshore
ONSHR	onshore
ORGPHC	orographic
OTLK	outlook
OTWZ	otherwise
OVC	overcast
OVR	over
OVRNG	overrunning
PCPN	precipitation

Figure H-2 Abbreviations

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

CONTRACTION	PLAIN LANGUAGE
PD	period
PL	ice pellets
PRECDD	preceded
PRECDS	precedes
PRES	pressure
PROG	prognostic, prognosis
PRSTG	persisting
PSG	passage, passing
PSN	position
PTCHY	patchy
PTLY	partly
RA	rain
RDG	ridge
RFRMG	reforming
RGN	region
RMNG	remaining
RPDLY	rapidly
RPRT	report
RSG	rising
RUF	rough
RVR	river
S	south
SCT	scattered
SCTR	sector
SE	southeast
SELY	southeasterly
SFC	surface
SH	shower
SHFT	shift
SHFTG	shifting
SHLW	shallow
SKC	sky clear
SLO	slow
SLOLY	slowly
SLY	southerly
SM	statute mile(s)
SML	small
SN	snow
SNRS	sunrise
SNST	sunset

CONTRACTION	PLAIN LANGUAGE
SPECI	special
SPRDG	spreading
SQ	squall
STBL	stable
STG	strong
STGTN	strengthen
STNRY	stationary
SEV	severe
SVRL	several
SW	southwest
SWLY	southwesterly
SXN	section
SYS	system
T	temperature
TCU	towering cumulus
TEMPO	temporary
THK	thick
THKNG	thickening
THN	thin
THNC	thence
THNG	thinning
THRU	through
THRUT	throughout
THSD	thousand
TILL	until
TRML	terminal
TROF	trough
TROWAL	trough of warm air aloft
TRRN	terrain
TS	thunderstorm
TURB	turbulence
TWD	toward
UNSTBL	unstable
UPR	upper
UPSLP	upslope
UTC	co-ordinated universal time
VC	vicinity
VLY	valley
VRB	variable
VIS	visibility

Figure H-3 Abbreviations

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

CONTRACTION	PLAIN LANGUAGE
VV	vertical visibility
W	west
WDLY	widely
WK	weak
WLY	westerly
WND	wind
WRM	warm
WS	wind shear
WV	wave
WX	weather
XCP	except
XT	extend
XTDG	extending
XTRM	extreme
XTSV	extensive
Z	ZULU (or UTC)

Figure H-4 Abbreviations

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.pdf

GFA Weather Symbols

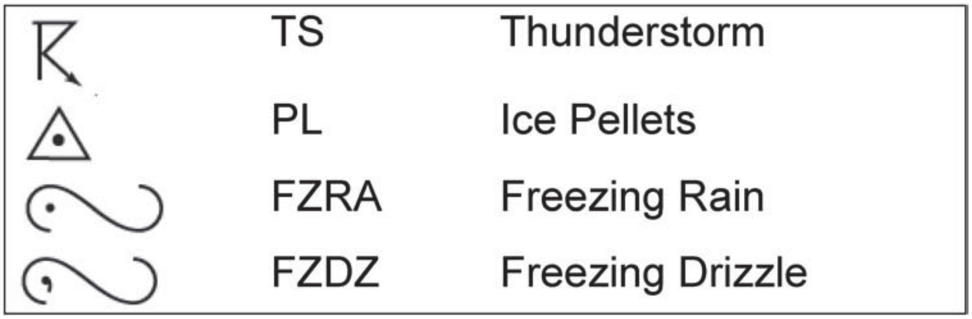

Figure I-1 Weather Symbols

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

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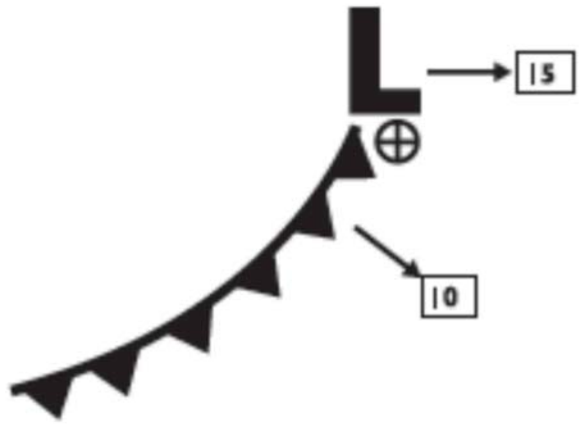


Figure J-1 Synoptic Features

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

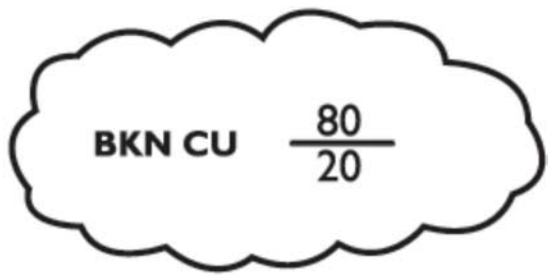


Figure J-2 Broken Cumulus Clouds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

Figure J-3 Scattered Clouds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

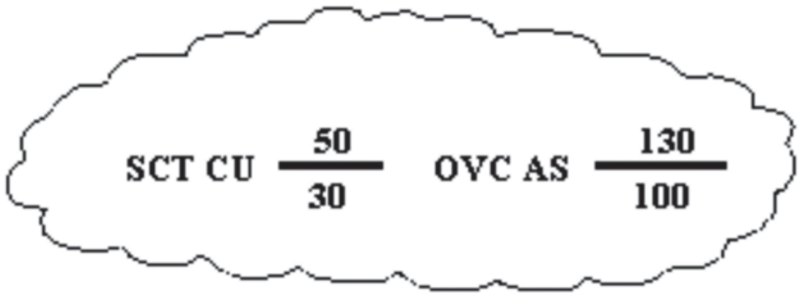


Figure J-4 Multiple Cloud Layers

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

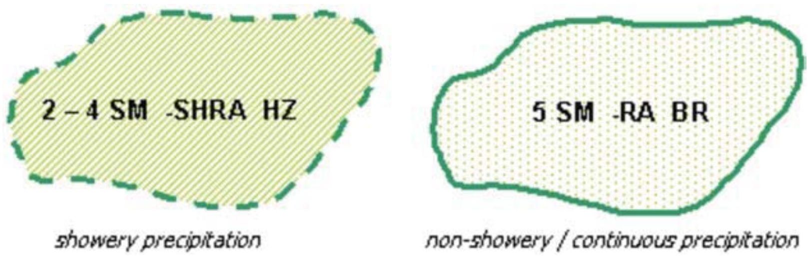


Figure J-5 Weather and Obstructions to Vision

Note. From Nav Canada, 2007, *Aviation Weather Website*. Retrieved October 28, 2008, from http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=info-gfa&*NoSession=NS_Inconnu&TypeDoc=gfa&Langue=anglais#abbr_symb*

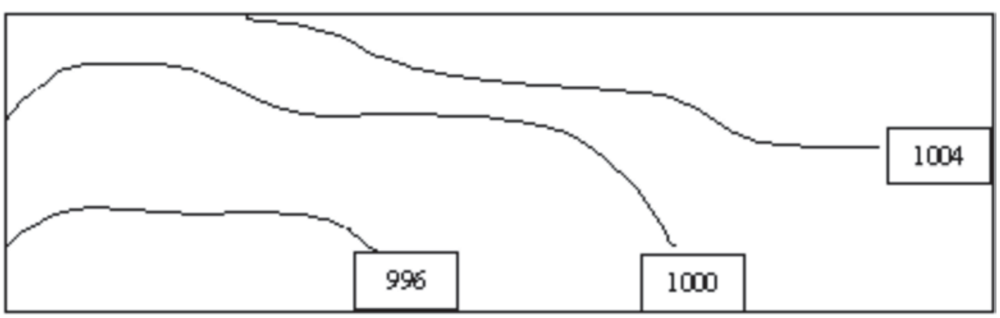


Figure J-6 Isobars

Note. From Nav Canada, 2007, *Aviation Weather Website*. Retrieved October 28, 2008, from http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=info-gfa&*NoSession=NS_Inconnu&TypeDoc=gfa&Langue=anglais#abbr_symb*

Figure J-7 Surface Winds

Note. From *Aeronautical Information Manual*. by Transport Canada, 2008, Retrieved October 27, 2008, from http://www.tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 1

EO M437.01 – DEFINE AIR NAVIGATION TERMS

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy the handout located at Attachment A for each cadet.

Prepare slides of the figures located at Attachment B.

Photocopy the Headings and Bearings Worksheet located at Attachment C for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1–3 to clarify, emphasize, and summarize navigation terms.

An in-class activity was chosen for TP 4 as it is an interactive way to reinforce bearings and headings, and confirm the cadets' comprehension of navigation terms.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to define air navigation terms.

IMPORTANCE

It is important for cadets to define air navigation terms to ensure a firm foundation in navigation before learning more advanced material. Knowledge of air navigation terms is essential for future aviation training and potential instructional duties at the squadron.

Teaching Point 1	Define meridians of longitude, parallels of latitude, geographical co-ordinates, and the relationship between time and longitude.
Time: 25 min	Method: Interactive Lecture

Use a large globe to point out the meridians of longitude and parallels of latitude.

MERIDIANS OF LONGITUDE

Meridians of longitude. Semicircles joining the true / geographic poles of the Earth.

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

Longitude is measured in degrees (°), minutes ('), and seconds ("). There are 60 minutes in a degree and 60 seconds in a minute.

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

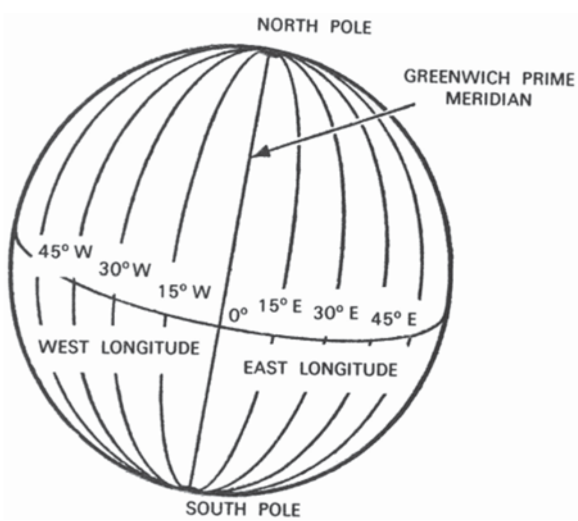


Figure 1 Meridians of Longitude

Note. From "Air Cadet Master Lesson Plans", 2007, *Cadets Canada: RCSU Pacific*. Retrieved November 14, 2007, from http://www.regions.cadets.ca/pac/aircad/resources/mlp_air_e.asp

PARALLELS OF LATITUDE

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

Equator. An imaginary line on the surface of the Earth equidistant from the poles.

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

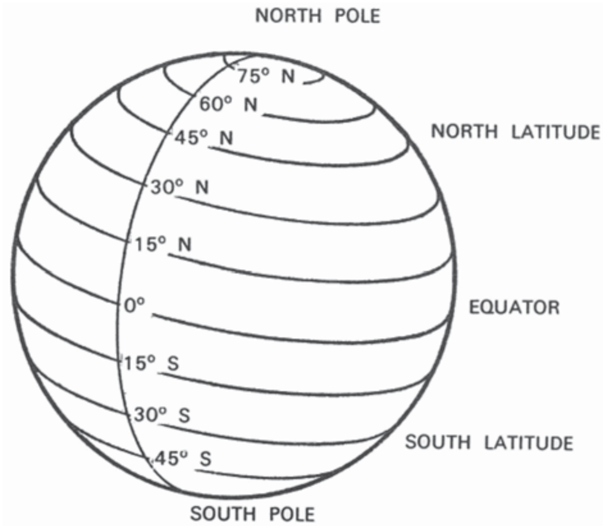


Figure 2 Parallels of Latitude

Note. From "Air Cadet Master Lesson Plans", 2007,*Cadets Canada: RCSU Pacific*. Retrieved November 14, 2007, from http://www.regions.cadets.ca/pac/aircad/resources/mlp_air_e.asp

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

- Lat is flat / fat; longitude is long.
- Latitude is like climbing up a ladder because it is north / south; longitude is like swinging across because it is east / west.

GEOGRAPHICAL CO-ORDINATES

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

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

Distribute the handout located at Attachment A to each cadet.

Have the cadets find markings on a line of latitude or longitude to represent 1 minute, 5 minutes, and 10 minutes using a local VFR Navigation Chart (VNC).

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

The location of the military airport at Trenton, Ont. has been chosen as an example because it appears on the sample VNC provided in the back of *From The Ground Up: Millennium Edition*.

The grid surrounding this airport can be found at Attachment A.

Select a major airport in the area and have the cadets find the coordinates using a local VNC.

THE RELATIONSHIP BETWEEN TIME AND LONGITUDE

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

For example:

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

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

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

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

UTC replaced Greenwich mean time (GMT) which was the universally accepted standard for the measurement of time until December, 1985.

UTC is the LMT for the prime meridian.

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

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

Tell the cadets how many hours are added to LMT to find UTC in their location.

Use a large globe to indicate the time zones.

The world is divided into 24 time zones, each 15 degrees of longitude (one hour) wide. When travelling westward into a new time zone, time is turned back one hour. When travelling eastward into a new time zone, time is turned ahead one hour.

One exception to this is Newfoundland Standard Time, which is 1/2 hour ahead of Atlantic Standard Time.

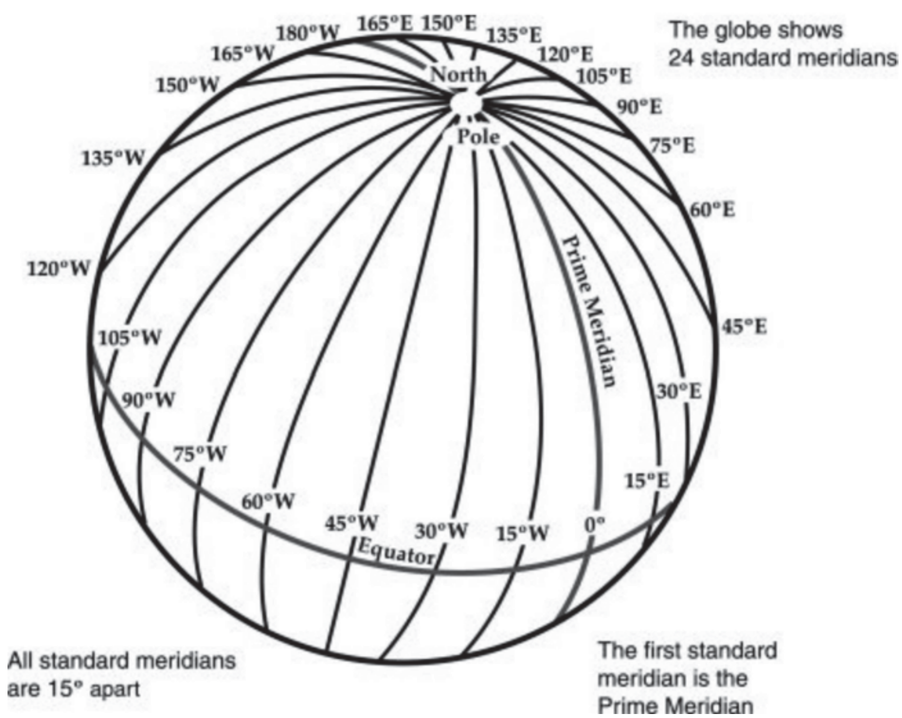
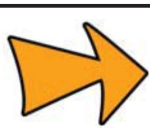


Figure 3 Meridians of Longitude

Note. From "Globe Lesson 12", *1-World Maps Online*, Copyright 2008 by 1-World Maps Online. Retrieved November 25, 2008, from http://www.worldmapsonline.com/LESSON-PLANS/6-global-time-globe-lesson-12.htm



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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What are meridians of longitude?

Q2. How are parallels of latitude measured?

Q3. What must be done to LMT in Canada to convert it to UTC?

ANTICIPATED ANSWERS:

A1. Semicircles joining the true / geographic poles of the Earth.

A2. From 0–90 degrees north and south of the equator.

A3. The appropriate number of hours must be added.

Teaching Point 2	**Define great circles and rhumb lines.**
Time: 10 min	Method: Interactive Lecture

GREAT CIRCLES

Show the slide of Figures B-1 and B-2 to the cadets.

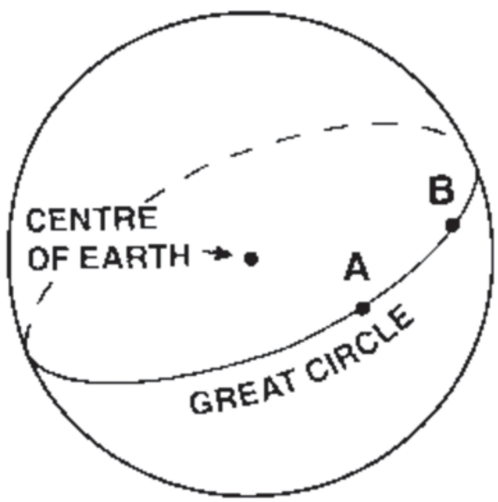


Figure 4 Great Circle

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

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

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

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

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

RHUMB LINES

Show the slide of Figures B-3 and B-4 to the cadets.

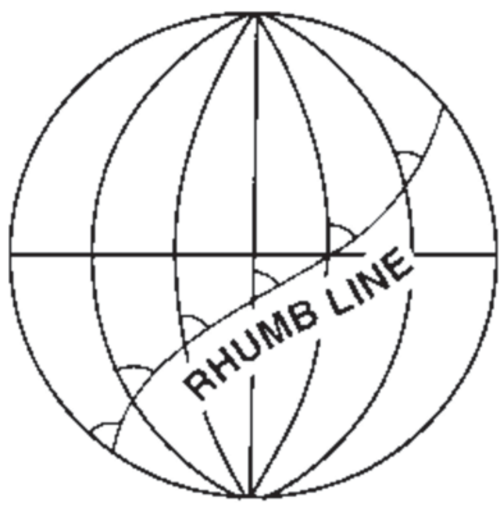


Figure 5 Rhumb Line

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

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

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

Show the slide of Figures B-5 and B-6 to the cadets.

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

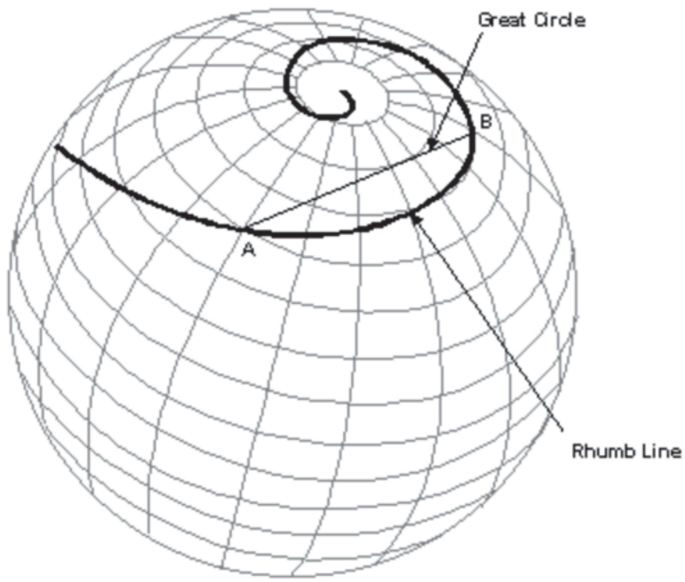


Figure 6 Great Circle and Rhumb Line

Note. From "Flights", *Navworld*. Retrieved November 26, 2008, http://www.navworld.com/navcerebrations/flights.htm

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CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is a great circle?

Q2. What is a rhumb line?

Q3. What is the advantage of following a rhumb line route?

ANTICIPATED ANSWERS:

A1. A circle on the surface of a sphere that passes through the centre of the sphere, cutting it into two equal parts.

A2. A curved line on the surface of the Earth, cutting all the meridians it meets at the same angle.

A3. The direction is constant, allowing a navigator to follow a constant heading.

Teaching Point 3 **Define headings and bearings.**

Time: 5 min Method: Interactive Lecture

HEADINGS AND BEARINGS

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

Show the slide of Figure B-7 to the cadets.

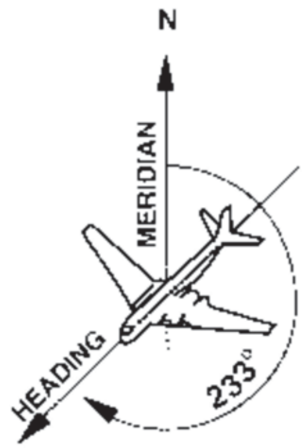

Figure 7 Heading

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

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

Show the slide of Figure B-8 to the cadets.

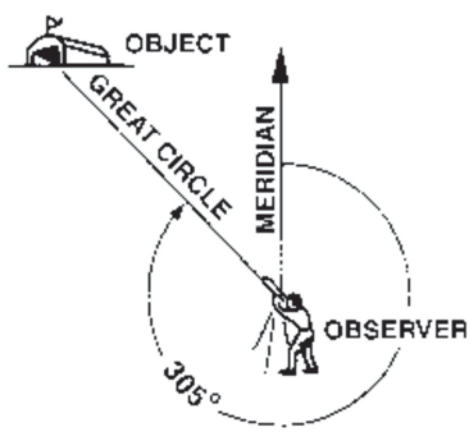

Figure 8 Bearing

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

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

Bearing. The angle between the meridian of longitude passing through the observer and the great circle that joins the observer to the object, measured clockwise from the meridian.

Headings and bearings are found using a compass.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. How is direction measured?

Q2. Define true heading.

Q3. Define bearing.

ANTICIPATED ANSWERS:

A1. In degrees clockwise from north.

A2. The angle between the meridian of longitude over which an airplane is flying and the line representing the direction the airplane's nose is pointing, measured clockwise from the meridian.

A3. The angle between the meridian of longitude passing through the observer and the great circle that joins the observer to the object, measured clockwise from the meridian.

Teaching Point 4	**Have the cadets take headings and bearings.**
Time: 10 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets take headings and bearings.

RESOURCES

- Douglas Protractor,
- Pen / Pencil, and
- Headings and Bearings Worksheet located at Attachment C.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Distribute a Douglas protractor to each cadet.
2. Distribute a Headings and Bearings Worksheet to each cadet.
3. Designate an object in the room as representing magnetic north.
4. Have the cadets take the magnetic headings of the aircraft in Section 1 of the worksheet.

5. Review and correct the answers.
6. Designate a different object in the room as representing true north.
7. Have the cadets take the bearing of the tower from the aircraft in Section 2 of the worksheet.
8. Review and correct the answers.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 4

The cadets' participation in the activity will serve as the confirmation of the TP.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. How many degrees of longitude are equal to one hour?

Q2. What is the shortest distance between two places on the surface of the Earth?

Q3. How are headings and bearings found?

ANTICIPATED ANSWERS:

A1. Fifteen.

A2. The shorter arc of the great circle joining them.

A3. Using a compass.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Future aviation training and instructional duties require knowledge of air navigation terms.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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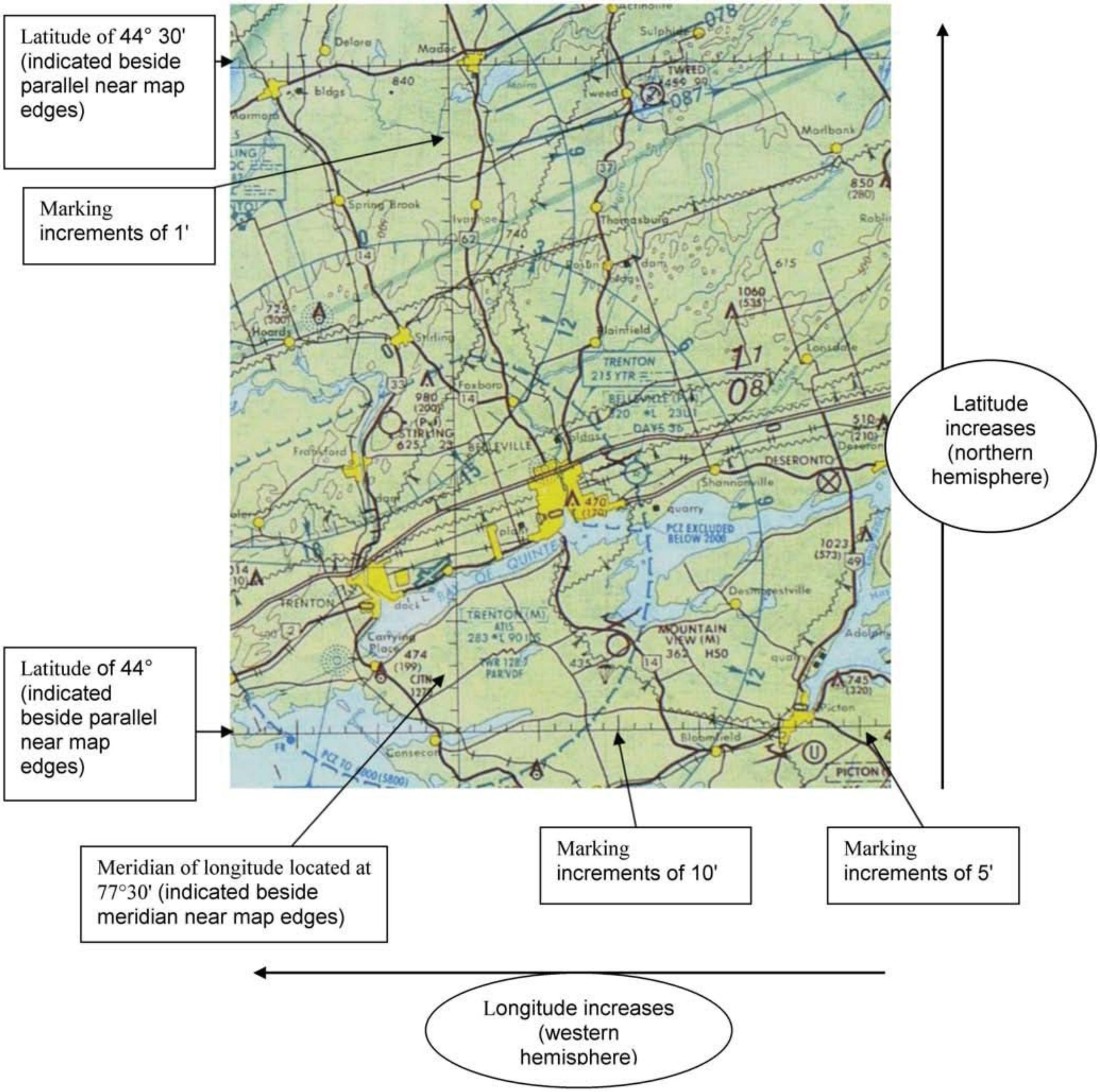

Figure A-1 Example of a VNC

Note. From *Toronto VFR Navigation Chart*, by Geomatics Canada, 2001, Ottawa, ON: Geomatics Canada Department of Natural Resources. Copyright 2001 by NAV CANADA and Her Majesty the Queen in Right of Canada.

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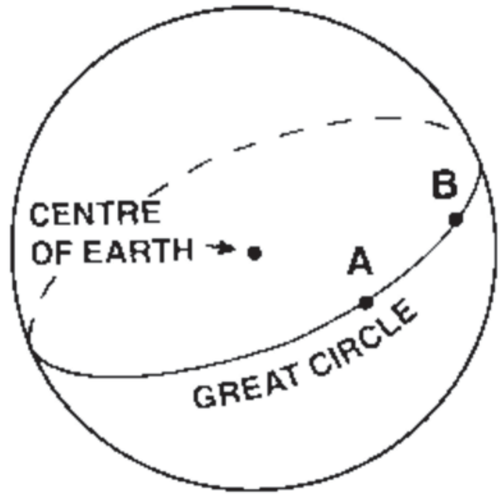


Figure B-1 Great Circle

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

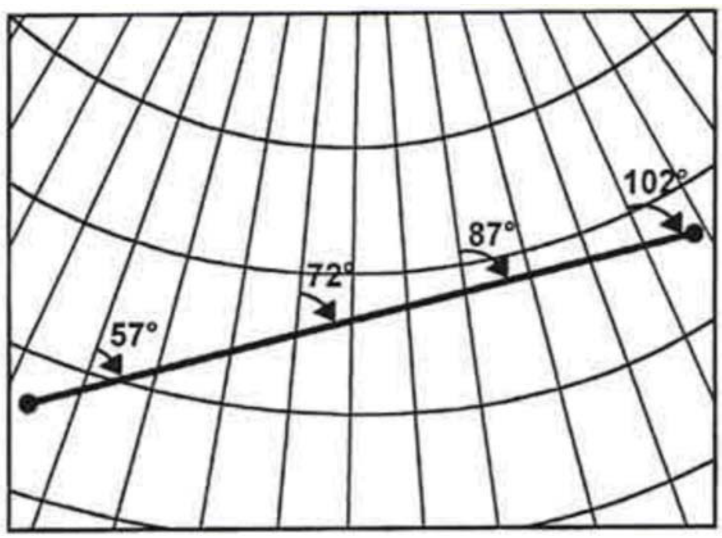


Figure B-2 Great Circle

Note. From "Navigation Basics", *Free Online Private Pilot Ground School*. Retrieved November 26, 2008, http://www.free-online-private-pilot-ground-school.com/navigation-basics.html

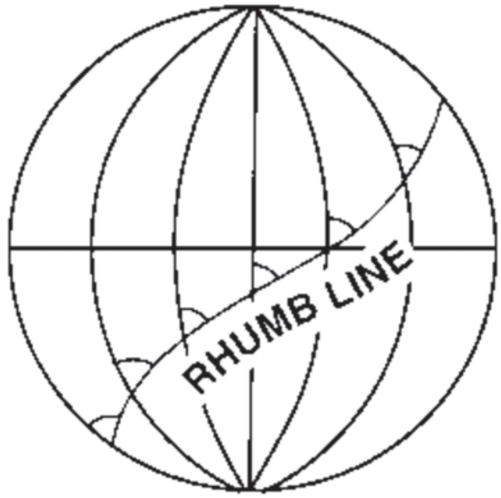


Figure B-3 Rhumb Line

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

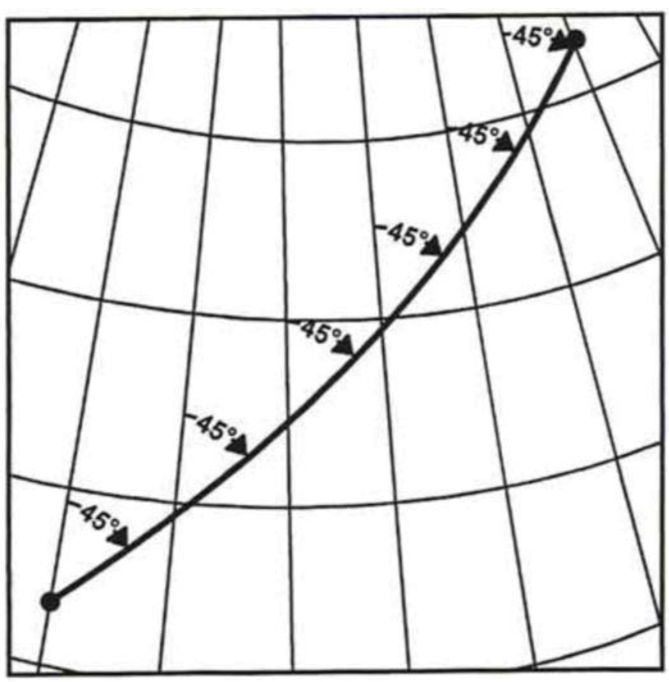


Figure B-4 Rhumb Line

Note. From "Navigation Basics", *Free Online Private Pilot Ground School*. Retrieved November 26, 2008, http://www.free-online-private-pilot-ground-school.com/navigation-basics.html

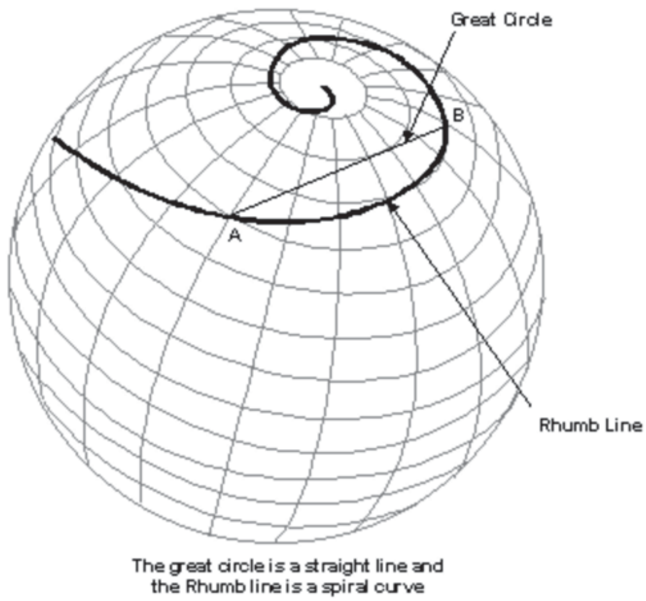


Figure B-5 Great Circle and Rhumb Line

Note. From "Flights", *Navworld*. Retrieved November 26, 2008, http://www.navworld.com/navcerebrations/flights.htm

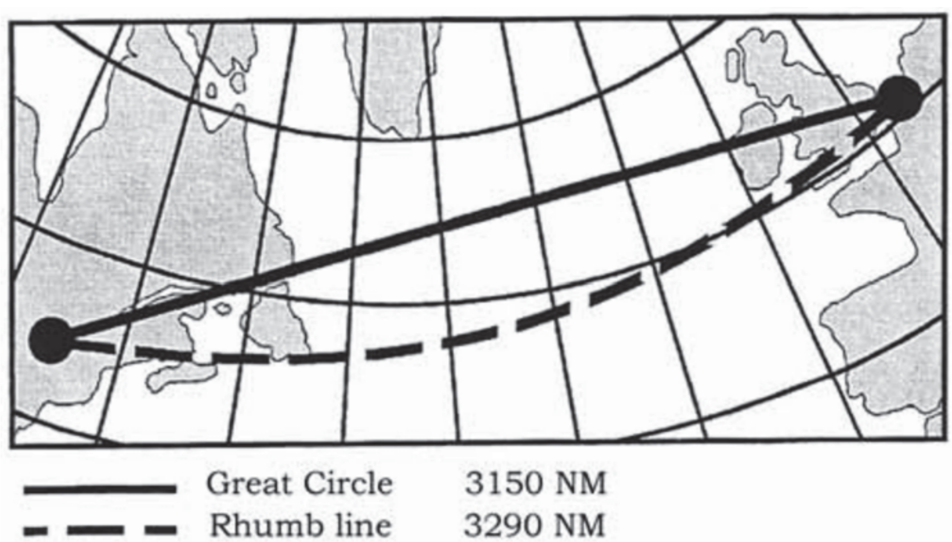


Figure B-6 Great Circle and Rhumb Line

Note. From "Navigation Basics", *Free Online Private Pilot Ground School*. Retrieved November 26, 2008, http://www.free-online-private-pilot-ground-school.com/navigation-basics.html

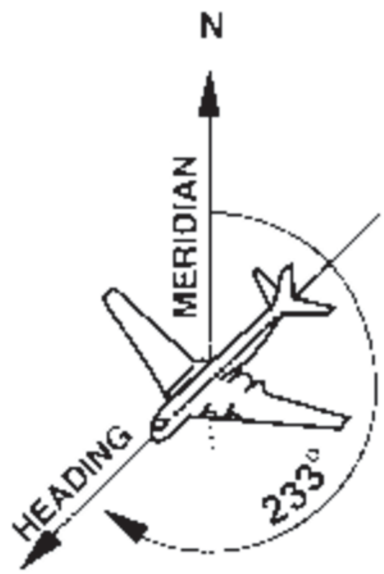


Figure B-7 Heading

Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

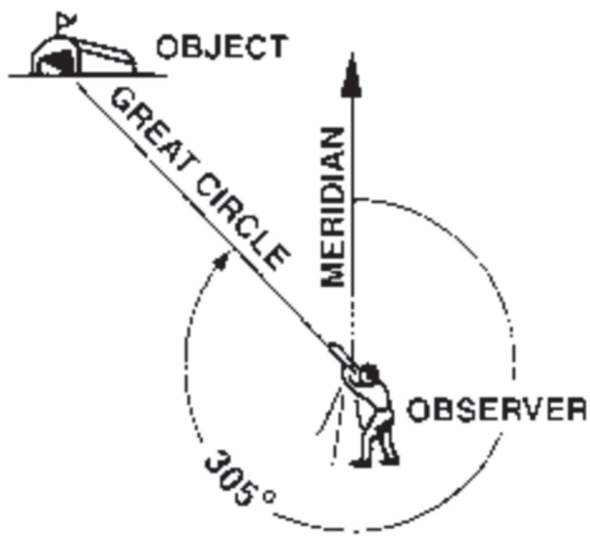
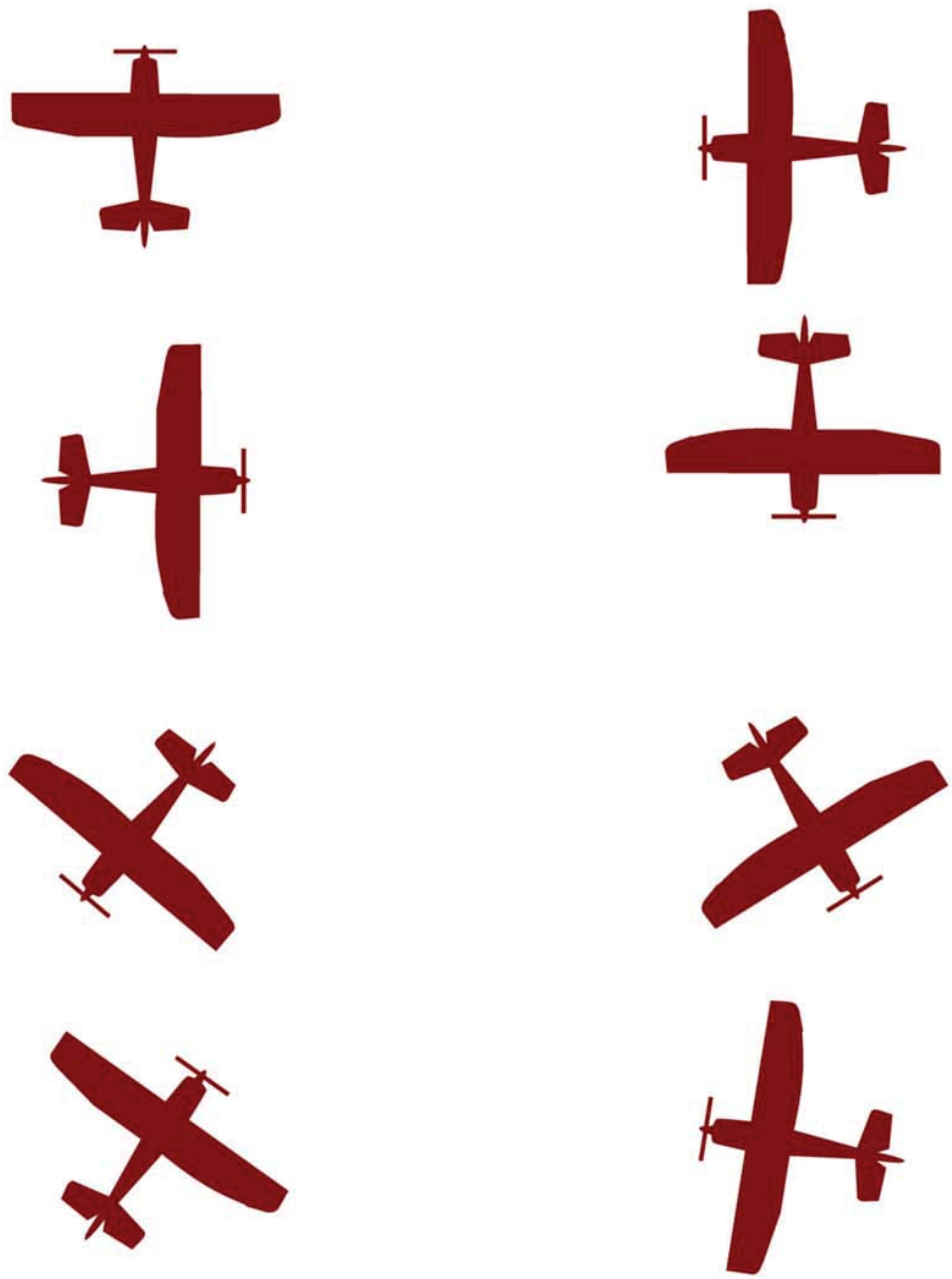


Figure B-8 Bearing

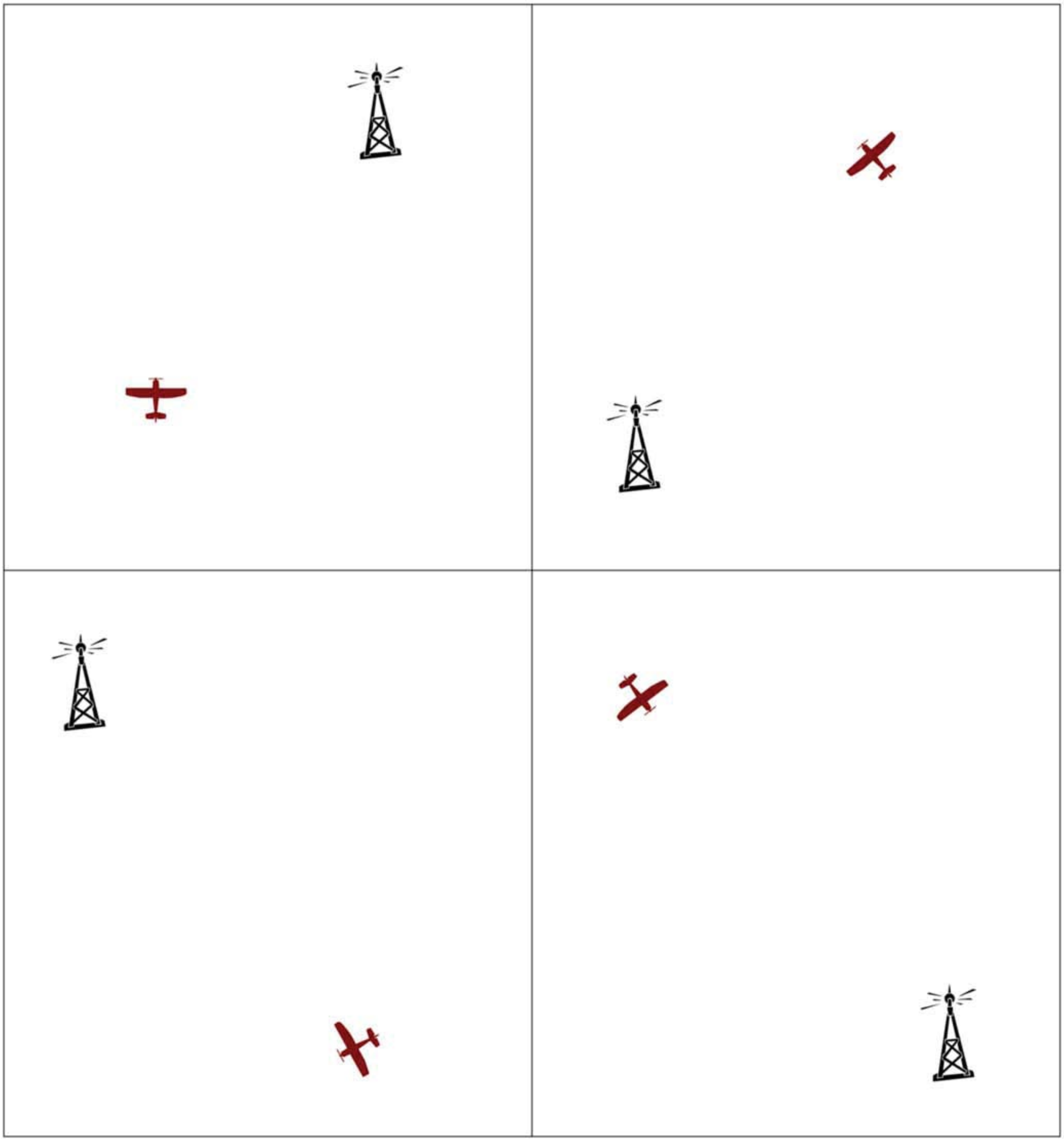
Note. From *From the Ground Up: Millennium Edition* (p. 177), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Headings and Bearings Worksheet

Section 1 – Take the Heading of Each Aircraft



Section 2 – Take the Bearing of the Tower from the Aircraft



ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 2

EO M437.02 – DESCRIBE THE MAGNETIC COMPASS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides of the figures located at Attachment A.

Photocopy the homework assignment located at Attachment B for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize the magnetic compass.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to describe the magnetic compass.

IMPORTANCE

It is important for the cadets to learn about the magnetic compass because the compass is a vital instrument used for navigation. The compass is often used as a reference for other instruments used in direction finding (such as the heading indicator). The cadets can apply this knowledge in a flight simulator and on a demonstration flight.

Teaching Point 1	**Describe the Earth's magnetism.**
Time: 5 min	Method: Interactive Lecture

THE EARTH'S MAGNETISM

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

Points of a Compass Rose

Show the slide of Figure A-1 to the cadets.

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

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. Where does the magnetic needle point?

Q2. What cardinal point does a bearing of 270 degrees represent?

Q3. What is your heading (in degrees) if you are flying northeast?

ANTICIPATED ANSWERS:

A1. Magnetic north.

A2. West.

A3. 45 degrees.

Teaching Point 2	**Describe the main parts of the magnetic compass.**
Time: 5 min	Method: Interactive Lecture

MAIN PARTS OF THE MAGNETIC COMPASS

Show the slide of Figure A-2 to the cadets.

Point out the parts of a magnetic compass using the examples of magnetic compasses.

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

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What does the lubber line indicate?

Q2. What part of the compass contains the numbers that are read?

Q3. What liquids are used in the compass bowl?

ANTICIPATED ANSWERS:

A1. The direction the airplane is heading.

A2. The compass card.

A3. Alcohol or white kerosene.

Teaching Point 3	**Describe variation.**
Time: 5 min	Method: Interactive Lecture

VARIATION

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

Show the slide of Figure A-3 to the cadets.

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

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

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

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

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

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

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

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. What is variation?

Q2. What are isogonic lines?

Q3. How is a magnetic heading calculated?

ANTICIPATED ANSWERS:

A1. The angle between true north and magnetic north.

A2. Isogonic lines join places of equal magnetic variation.

A3. By adding westerly variation (subtracting easterly variation) to (from) the true heading.

Teaching Point 4	**Describe compass errors.**
Time: 10 min	Method: Interactive Lecture

Deviation

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

Demonstrate deviation by placing a compass near a laptop computer or other electrical device.

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

Show the slide of Figure A-4 to the cadets.

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

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

Magnetic Dip

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

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

Northerly Turning Error

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

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

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

Acceleration and Deceleration Errors

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

Show the slide of Figure A-5 to the cadets.

On east and west headings:

- acceleration causes the compass to register a turn toward north, and
- deceleration causes the compass to register a turn toward south.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS:

Q1. For what does a compass card indicate corrections?

Q2. What does a turn from the north cause a compass to do?

Q3. On what headings do acceleration and deceleration cause the compass to register a turn?

ANTICIPATED ANSWERS:

A1. Deviation.

A2. Lag.

A3. East and west.

END OF LESSON CONFIRMATION

The cadets' completion of the homework assignment will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Have the cadets complete the Magnetic Headings Worksheet located at Attachment B. Use the answer key located at Attachment C to review their answers.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

To use a magnetic compass, the underlying principles must be understood. A compass is a common instrument in aviation and can act as a reference for setting other instruments. Magnetic compasses are useful not only in aviation but also on the ground and on the water.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

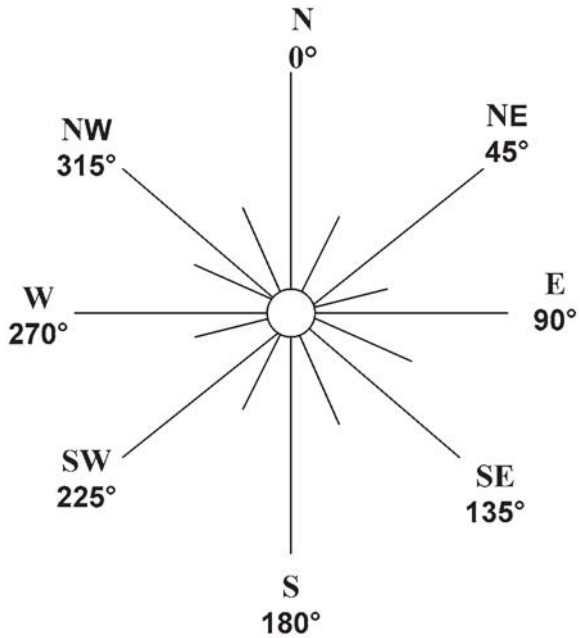


Figure A-1 Points on a Compass Rose

Note. Created by Director Cadets 3, 2007, Ottawa, ON: Department of National Defence.

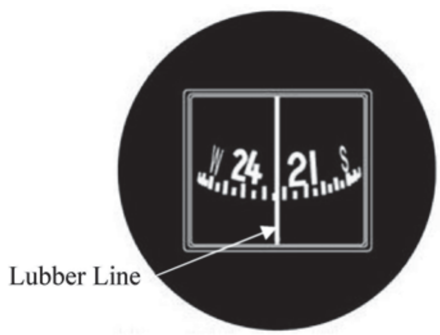


Figure A-2 Lubber Line

Note. From "Magnetic Compass", by North American Powered Parachute Federation, 2001, *Flight Instruments*, Copyright 2001 by North American Powered Parachute Federation. Retrieved November 8, 2007, from http://www.nappf.com/nappf_flight_instruments_files/image008.jpg

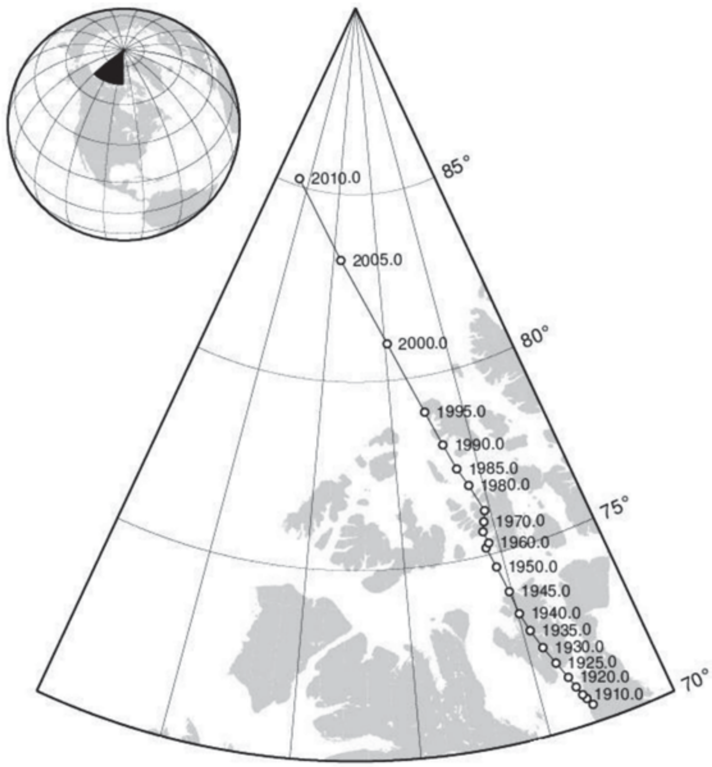


Figure A-3 Location of the Magnetic North Pole

Note. From "Locations of the North Magnetic Pole from IGRF-10", by K. Korhonen, *Helsinki University of Technology*. Retrieved November 8, 2007, from http://users.tkk.fi/~kkorhon1/nmplocs.png

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

Figure A-4 Compass Correction Card

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

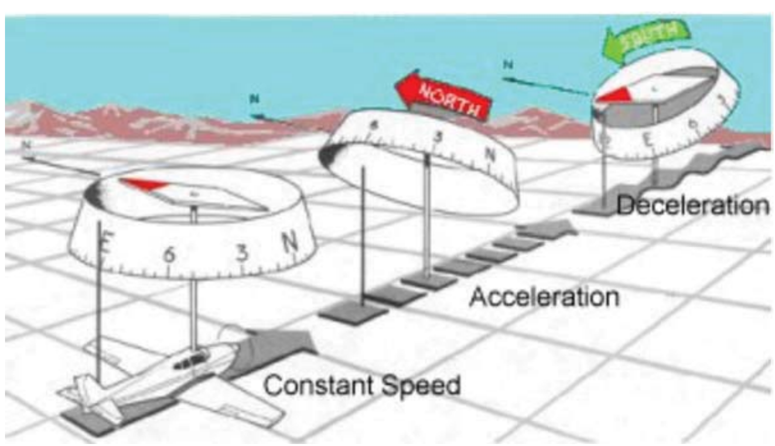


Figure A-5 Acceleration and Deceleration Errors

Note. From "Magnetism and the Magnetic Compass ", by *Pilot's Web*.
Retrieved November 8, 2007, from http://pilotsweb.com/navigate/art/accel.jpg

MAGNETIC HEADINGS WORKSHEET

Fill in the missing values.

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

Sample Compass Correction Card

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

Fill in the missing values.

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

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MAGNETIC HEADINGS ANSWER KEY

Fill in the missing values.

	Variation	True Heading	Magnetic Heading
1.	8° west	120°	**128°**
2.	2° east	270°	**268°**
3.	11° east	010°	**359°**
4.	15° west	350°	**005°**
5.	22° east	180°	**158°**
6.	**11° west**	090°	101°
7.	**5° east**	085°	080°
8.	**6° west**	359°	005°
9.	**12° west**	254°	266°
10.	**4° east**	122°	118°
11.	9° east	**122°**	113°
12.	3° west	**354°**	357°
13.	15° west	**330°**	345°
14.	12° east	**136°**	124°
15.	2° west	**178°**	180°

Sample Compass Correction Card

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

Fill in the missing values.

	Magnetic Heading	Compass Heading
1.	020°	**020°**
2.	161°	**163°**
3.	345°	**344°**
4.	**082°**	080°
5.	**213°**	215°

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 3

EO C437.01 – SOLVE NAVIGATION PROBLEMS WITH A MANUAL FLIGHT COMPUTER

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare slides of the figures located at Attachment A.

Photocopy the Navigation Problems Worksheet located at Attachment B for each cadet.

Assistant instructors may be required for this lesson.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

A demonstration and performance was chosen for this lesson as it allows the instructor to explain and demonstrate solving navigation problems with a manual flight computer while providing an opportunity for the cadets to practice this skill under supervision.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have solved navigation problems with a manual flight computer.

IMPORTANCE

It is important for cadets to be able to solve navigation problems with a manual flight computer as it is an important skill that is required for flight planning and en route navigation. Solving navigation problems provides skills for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

For this lesson, it is recommended that the instruction take the following format:

1. Explain and demonstrate the technique to use the manual flight computer while the cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice using the manual flight computer to solve navigation problems.

Note: Assistant instructors may be used to monitor the cadets' performance.

Teaching Point 1 **Demonstrate how to use a manual flight computer to convert units of measure and have the cadets practice converting units of measure.**

Time: 25 min Method: Demonstration and Performance

MANUAL FLIGHT COMPUTER

Navigation calculations are simplified by the use of a flight computer. Most manual flight computers consist of two sides: a circular slide rule and a wind side.

Show the slide of Figure A-1 to the cadets.

The instructions for using a manual flight computer are often printed directly on the flight computer.

Circular Slide Rule

The circular slide rule can be used to solve any problem of multiplication, division, or proportion. There are three scales printed on the circular slide rule. The outer scale is fixed to the computer. The two inner scales are printed together on a disc that may be rotated to any position opposite the outer scale.

Show the slide of Figure A-2 to the cadets.

The outer scale represents miles, gallons, true airspeed and corrected altitude. The inner scale represents time in minutes, calibrated airspeed, and calibrated altitude. The third scale represents time in hours and minutes.

The figures on the circular slide rule may represent any proportion or multiple of 10. For example, 10 on the outer scale may represent 1, 10, or 100; 45 may represent 4.5, 45, or 450.

CONVERTING UNITS OF MEASURE

One of the most common types of calculations a pilot has to make is converting from one unit of measure to another. Fuel is sold by the litre, but fuel quantities and consumption are usually specified in the aircraft manual in gallons. Wind speeds are reported in knots, but the airspeed indicator (ASI) may be in statute miles per hour.

Using the circular slide rule for conversion calculations is a simple process. Rotate the inner scale to the correct position, locate the original quantity / measure on the outer scale, and read the converted quantity / measure from the inner scale, opposite to the appropriate marking.

Convert Between Nautical and Statute Miles

To convert between nautical and statute miles:

1. Rotate the inner scale until the known number of miles is under the appropriate index (NAUT or STAT).
2. Read the converted number of miles under the other index.

For example, to convert 90 nautical miles to statute miles:

1. Rotate the inner scale until 90 is under the nautical miles index.
2. Read the number of statue miles under the statue miles index (104 statute miles).

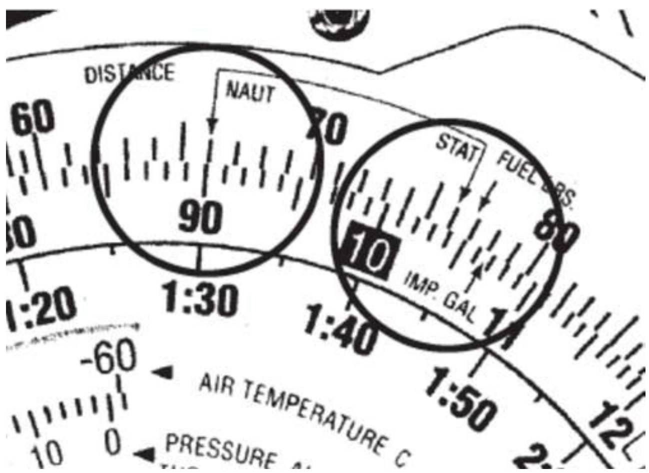

Figure 1 Nautical and Statute Mile Indexes

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

Convert Between Miles and Kilometres

To convert between miles and kilometres:

1. Rotate the inner scale until the known number is under the appropriate index (NAUT, STAT, or KM).
2. Read the converted number under the desired index.

For example, to convert 115 statute miles to kilometres:

1. Rotate the inner scale until 115 is under the statute miles index.
2. Read the number of kilometres under the kilometres index (185 km).

Figure 2 Statute Mile and Kilometre Indexes

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

Convert Between Imperial and US Gallons

To convert between imperial and US gallons:

1. Rotate the inner scale until the imperial and US gallon indexes are aligned.
2. Locate the known quantity (outer scale for imperial gallons and inner scale for US gallons) and read the desired quantity on the opposite scale.

For example, to convert 55 imperial gallons to US gallons:

1. Rotate the inner scale until the imperial and US gallon indexes are aligned.
2. Locate 55 on the outer scale and read the quantity of US gallons on the inner scale (66 US gallons).

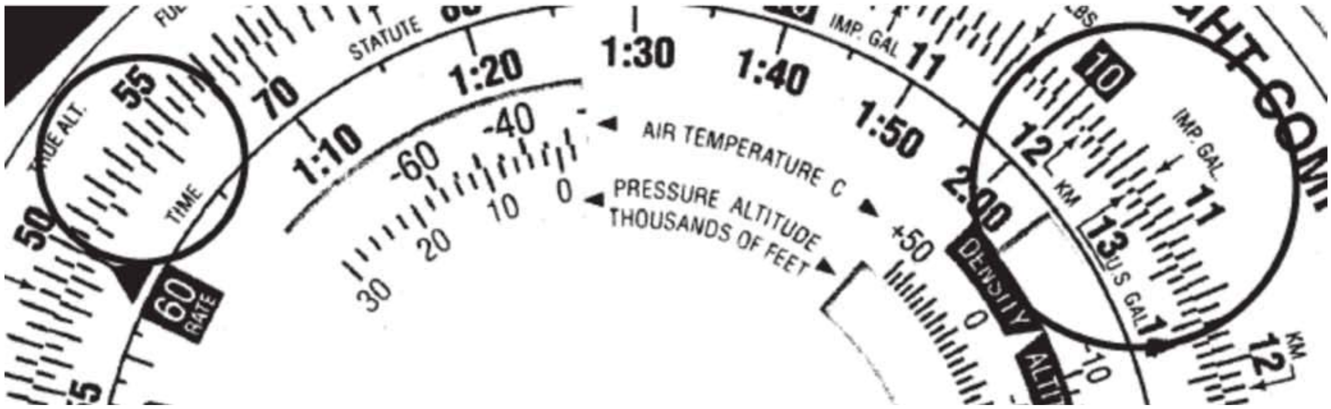

Figure 3 US and Imperial Gallon Indexes

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

Convert Between Gallons and Litres

To convert between gallons and litres:

1. Rotate the inner scale until the litres index is aligned with the appropriate gallon index.
2. Locate the known quantity and read the desired quantity on the opposite scale.

For example, to convert 100 L to US gallons:

1. Rotate the inner scale until the litres index is aligned with the US gallon index.
2. Locate 100 on the outer scale and read the quantity of US gallons on the inner scale (26 US gallons).

Convert Between Pounds and Kilograms

To convert between pounds and kilograms:

1. Rotate the inner scale until the pounds index is aligned with the kilograms index.
2. Locate the known quantity and read the desired quantity on the opposite scale.

For example, to convert 100 pounds to kilograms:

1. Rotate the inner scale until the pounds index is aligned with the kilograms index.
2. Locate 100 on the outer scale and read the quantity of kilograms on the inner scale (45 kg).

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to have the cadets practice converting units of measure using a manual flight computer.

RESOURCES

- Pen / pencil,
- Manual flight computer,
- Navigation Problems Worksheet located at Attachment B, and
- Navigation Problems Answer Key located at Attachment C.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Distribute a manual flight computer and a Navigation Problems Worksheet to each cadet.
2. Have the cadets complete Part 1 of the worksheet using the manual flight computer.
3. Review the answers using the answer key located at Attachment C.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 1

The cadets' participation in the activity will serve as the confirmation of this TP.

Teaching Point 2	**Demonstrate how to use a manual flight computer to calculate speed, distance, and time and have the cadets practice calculating speed, distance, and time.**
Time: 25 min	Method: Demonstration and Performance

SPEED, DISTANCE, AND TIME PROBLEMS

The rate arrow on the disk is always set to indicate a value per hour on the outer scale. There are three basic types of speed-time-distance problems. In two types of problems the speed is known, in the third, the speed is the unknown.

When solving speed, distance, and time problems, the units have to agree. For example, if the speed is in knots, the distance has to be in nautical miles and the time in hours.

If the units do not agree, use the circular slide rule to perform the required conversions to make the units agree before attempting to solve the problem.

Calculating Time (Speed and Distance are Known)

To calculate time when speed and distance are known:

1. Rotate the inner scale until the rate arrow is opposite the speed.
2. Locate the distance on the outer scale.
3. Read the time from the inner scale, opposite the distance.

For example, to calculate the time en route if the speed is 150 knots and the distance is 245 nautical miles:

1. Rotate the inner scale until the rate arrow is opposite 150.
2. Locate 245 on the outer scale.
3. Read the time en route from the inner scale, opposite 245 (1 hour and 38 minutes).

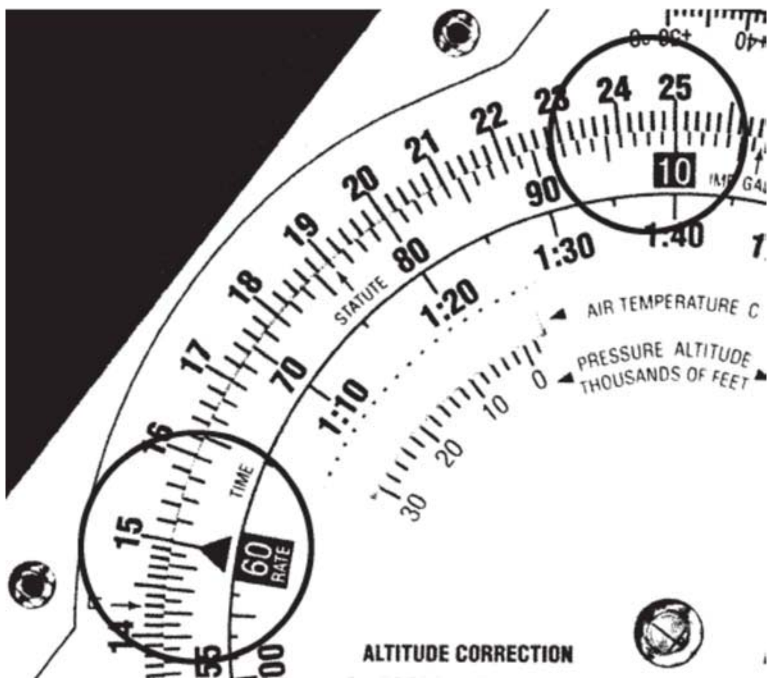

Figure 4 Rate Arrow, Speed, Distance, and Time

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

For example, to calculate the time en route if the speed is 120 knots and the distance is 100 statute miles:

1. Convert the distance to nautical miles (87).
2. Rotate the inner scale until the rate arrow is opposite 120.
3. Locate 87 on the outer scale.
4. Read the time en route from the inner scale, opposite 87 (44 minutes).

When calculating time en route, use the aircraft's groundspeed, not the airspeed.

Calculating Distance (Speed and Time are Known)

To calculate distance when speed and time are known:

1. Rotate the inner scale until the rate arrow is opposite the speed.
2. Locate the time on the inner scale.
3. Read the distance from the outer scale, opposite the time.

For example, to calculate the distance if the speed is 125 knots and the time en route is 4.5 hours:

1. Rotate the inner scale until the rate arrow is opposite 125.
2. Locate 4:30 on the inner scale.
3. Read the distance from the outer scale, opposite 4:30 (564 nautical miles).

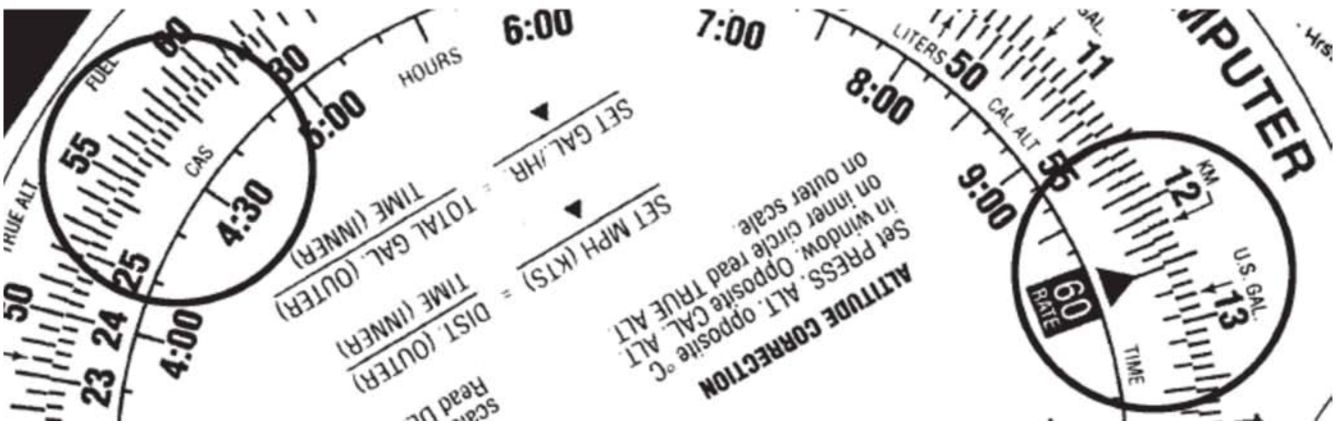

Figure 5 Rate Arrow, Speed, Distance, and Time

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

When calculating distance, use the aircraft's groundspeed, not the airspeed.

Calculating Speed (Distance and Time are Known)

To calculate speed when distance and time are known:

1. Rotate the inner scale until the distance is opposite the time.
2. Locate the rate arrow.
3. Read the speed from the outer scale, opposite the rate arrow.

For example, to calculate the speed if the distance is 26 nautical miles and the time en route is 13 minutes:

1. Rotate the inner scale until 26 is opposite 13.
2. Locate the rate arrow.
3. Read the speed from the outer scale, opposite the rate arrow (120 knots).

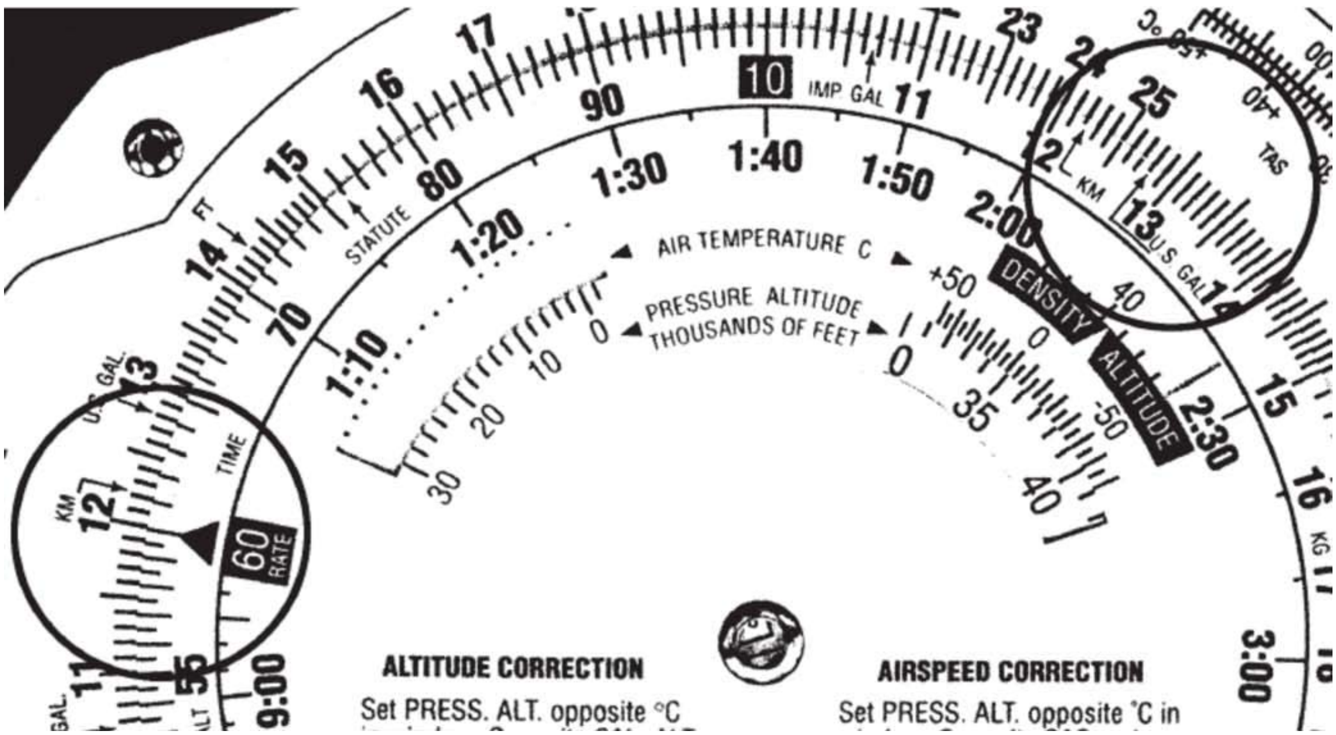

Figure 6   Rate Arrow, Speed, Distance, and Time

Note. From "Air Classics E6-B Flight Computer Instructions", *Aviation Supplies and Academics, Inc*. Retrieved November 26, 2008, from http://www.asa2fly.com/files/support/E6B_Manual.pdf

When calculating speed from distance and time, it is the groundspeed that is being calculated, not the airspeed.

ACTIVITY

Time: 10 min

OBJECTIVE

The objective of this activity is to have the cadets practice calculating speed, distance, and time using a manual flight computer.

RESOURCES

- Pen / pencil,
- Manual flight computer,

- Navigation Problems Worksheet located at Attachment B, and
- Navigation Problems Answer Key located at Attachment C.

ACTIVITY LAYOUT

Nil.

ACTIVITY INSTRUCTIONS

1. Have the cadets complete Part 2 of the worksheet using the manual flight computer.
2. Review the answers using the answer key located at Attachment C.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' completion of the Navigation Problems Worksheet will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Additional time may be required for the cadets to complete the worksheet.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Flight planning and navigation relies on being able to solve navigation problems. Being able to use a manual flight computer makes solving navigation problems faster and easier.

INSTRUCTOR NOTES / REMARKS

Assistant instructors may be required for this lesson.

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

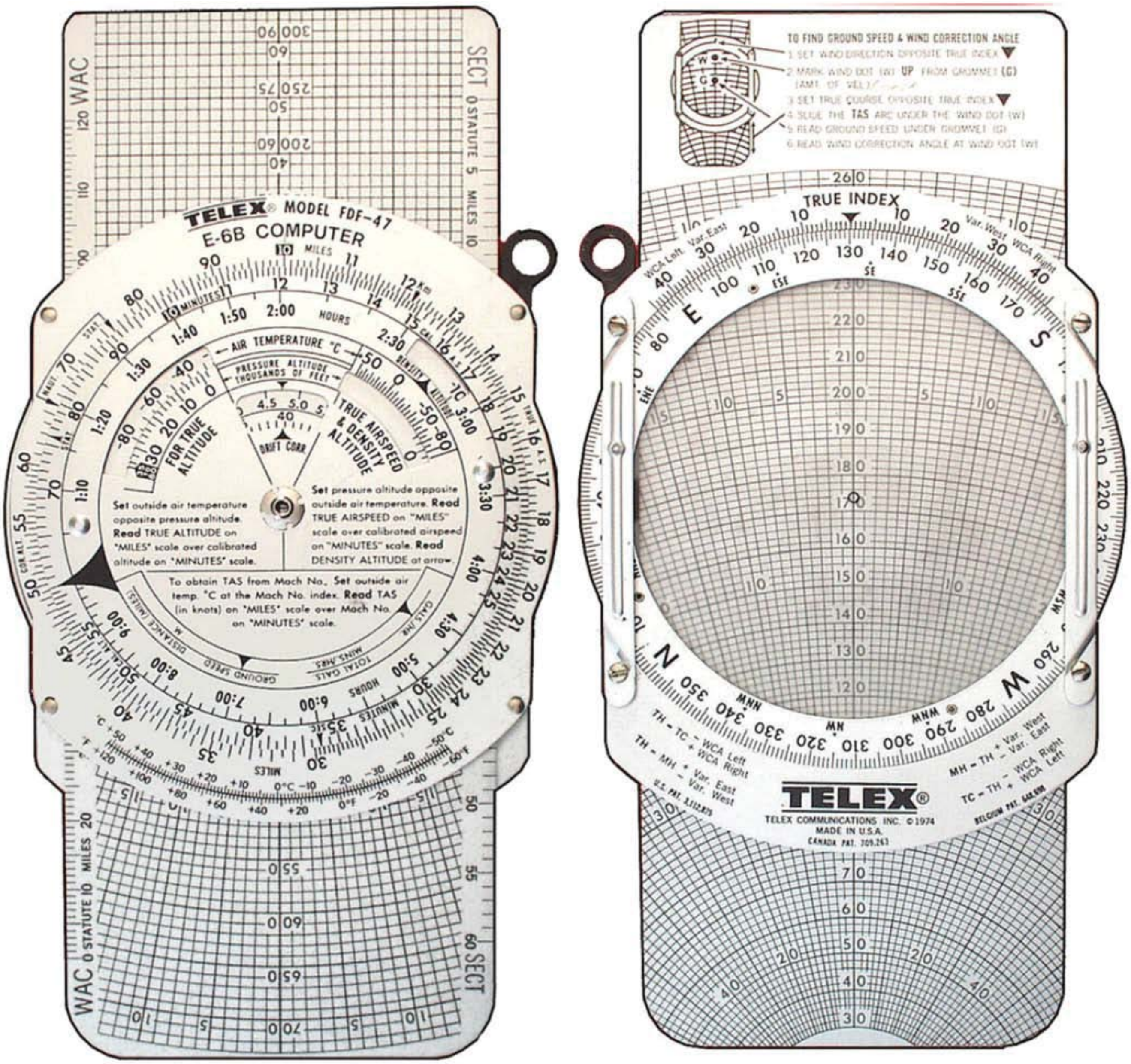

Figure A-1 E6B Manual Flight Computer

Note. From "Slide Rule Catalog", *Dutch Circle of Slide Rule Collectors*. Retrieved November 26, 2008, from http://www.rekeninstrumenten.nl/pages%20and%20pictures/25261.jpg

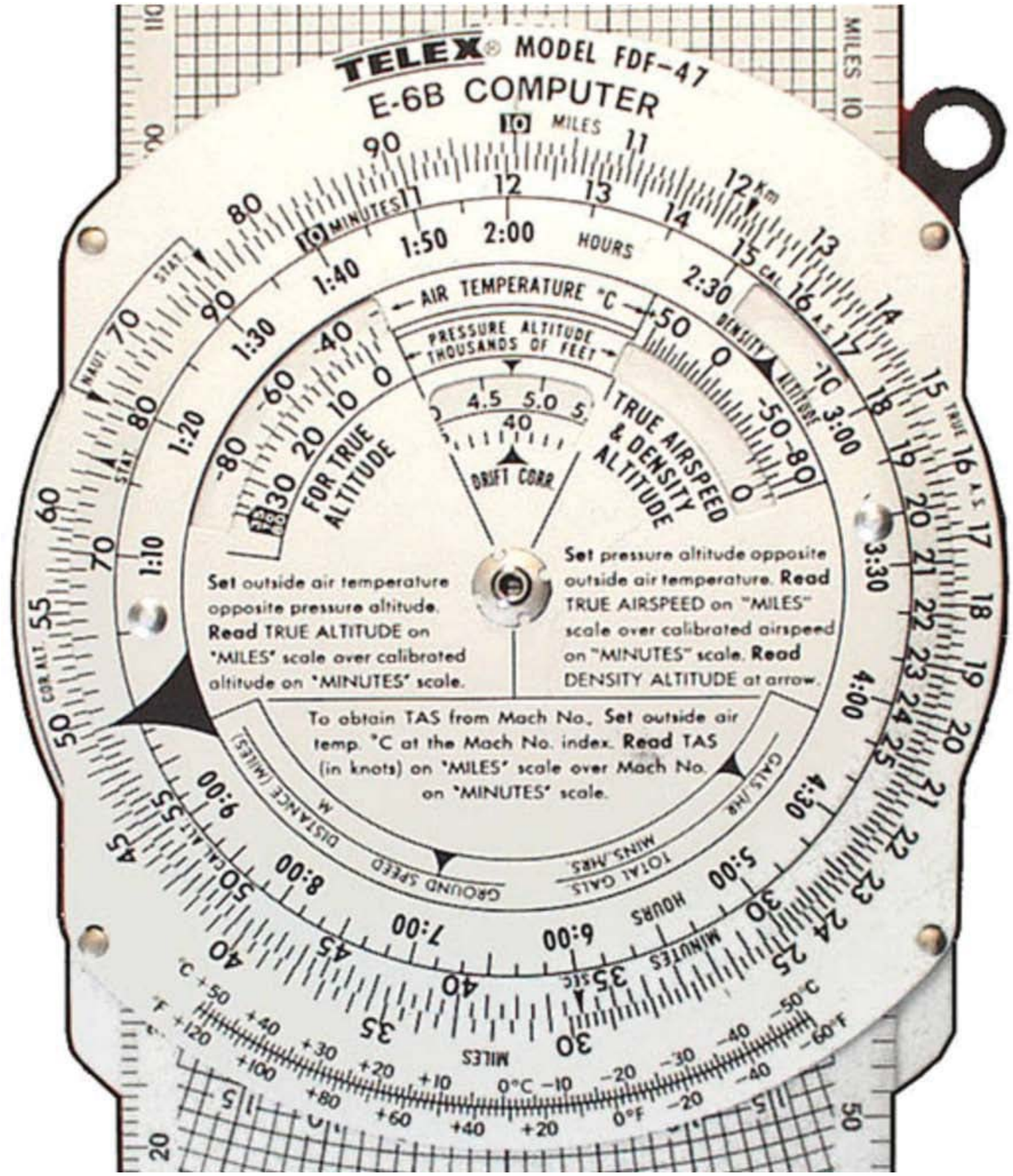

Figure A-2 E6B Circular Slide Rule

Note. From "Slide Rule Catalog", *Dutch Circle of Slide Rule Collectors*. Retrieved November 26, 2008, from http://www.rekeninstrumenten.nl/pages%20and%20pictures/25261.jpg

Navigation Problems Worksheet

Part 1

Convert		To		Convert		To	
123	nautical miles	_______	statute miles	23	nautical miles	_______	statute miles
99	statute miles	_______	nautical miles	1000	statute miles	_______	nautical miles
400	statute miles	_______	km	85	statute miles	_______	km
25	km	_______	statute miles	110	km	_______	statute miles
156	km	_______	nautical miles	93	km	_______	nautical miles
225	nautical miles	_______	km	48	nautical miles	_______	km
10	US gallons	_______	gallons	150	US gallons	_______	gallons
150	US gallons	_______	L	35	US gallons	_______	L
35	gallons	_______	US gallons	10	gallons	_______	US gallons
48	gallons	_______	L	225	gallons	_______	L
93	L	_______	gallons	156	L	_______	gallons
110	L	_______	US gallons	25	L	_______	US gallons
55	pounds	_______	kg	400	pounds	_______	kg
85	kg	_______	pounds	99	kg	_______	pounds
1000	feet	_______	m	123	feet	_______	m
23	m	_______	feet	55	m	_______	feet

Part 2

Calculate the missing values.

Speed	Distance	Time
130 knots	100 nautical miles	_______
85 knots	_______	2.5 hours
_______	250 nautical miles	4 hours 15 minutes
_______	25 nautical miles	5 minutes
65 knots	200 statute miles	_______
78 miles per hour	55 nautical miles	_______
330 km/h	300 km	_______
95 km/h	45 nautical miles	_______
_______	1000 km	320 minutes
_______	55 nautical miles	2 minutes
122 miles per hour	_______	1.3 hours
101 knots	_______	45 minutes
150 knots	5525 m	_______

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Navigation Problems Answer Key

Part 1

Convert		To		Convert		To	
123	nautical miles	**142**	statute miles	23	nautical miles	**26**	statute miles
99	statute miles	**86**	nautical miles	1000	statute miles	**869**	nautical miles
400	statute miles	**644**	km	85	statute miles	**137**	km
25	km	**16**	statute miles	110	km	**68**	statute miles
156	km	**84**	nautical miles	93	km	**50**	nautical miles
225	nautical miles	**417**	km	48	nautical miles	**89**	km
10	US gallons	**8**	gallons	150	US gallons	**125**	gallons
150	US gallons	**568**	L	35	US gallons	**132**	L
35	gallons	**42**	US gallons	10	gallons	**12**	US gallons
48	gallons	**218**	L	225	gallons	**1023**	L
93	L	**20**	gallons	156	L	**34**	gallons
110	L	**29**	US gallons	25	L	**7**	US gallons
55	pounds	**25**	kg	400	pounds	**181**	kg
85	kg	**187**	pounds	99	kg	**218**	pounds
1000	feet	**305**	m	123	feet	**37**	m
23	m	**75**	feet	55	m	**180**	feet

Part 2

Calculate the missing values.

Speed	Distance	Time
130 knots	100 nautical miles	**46 minutes**
85 knots	**213 nautical miles**	2.5 hours
59 knots	250 nautical miles	4 hours 15 minutes
300 knots	25 nautical miles	5 minutes
65 knots	200 statute miles	**2 hours 41 minutes**
78 miles per hour	55 nautical miles	**48 minutes**
330 km/h	300 km	**55 minutes**
95 km/h	45 nautical miles	**52 minutes**
188 km/h	1000 km	320 minutes
1650 knots	55 nautical miles	2 minutes
122 miles per hour	**159 statute miles**	1.3 hours
101 knots	**76 nautical miles**	45 minutes
150 knots	5525 m	**1 minute**

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 4

EO C437.02 – USE A VISUAL FLIGHT RULES (VFR) NAVIGATION CHART (VNC)

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Select coordinates of landmarks on a local VNC.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to clarify, emphasize, and summarize types of projections and aeronautical charts.

A demonstration and performance was chosen for TPs 3–6 as it allows the instructor to explain and demonstrate using a VNC while providing an opportunity for the cadets to practice using a VNC under supervision.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall have used a VNC.

IMPORTANCE

It is important for cadets to use a VNC as it is a skill required for flight planning and en route navigation. The VNC is the principal chart used in flight at low altitudes and slow speeds. Many of the skills used with this chart are transferable to other types of maps both in the air and on the ground. Knowledge of this material is essential for future aviation training and potential instructional duties at the squadron.

Teaching Point 1	**Explain types of projections.**
Time: 5 min	Method: Interactive Lecture

Earth is a sphere, so its surface cannot be represented accurately on a flat plane. Therefore, a map shows a portion of the Earth's surface with some distortion. There are four basic elements in map construction:

- areas,
- shapes,
- bearings, and
- distances.

Depending on the particular purpose of the map, one or more of these elements is preserved with minimal distortion, with the most distortion in the remaining elements.

Using the globe and the sheet of construction paper, demonstrate the impossibility of wrapping the sheet around the globe smoothly to create a chart.

The two principal types of chart projections used in air navigation charts are:

- the Lambert Conformal Conic Projection, and
- the Transverse Mercator Projection.

THE LAMBERT CONFORMAL CONIC PROJECTION

Using the globe and the sheet of construction paper, demonstrate superimposing a cone over the surface of the globe.

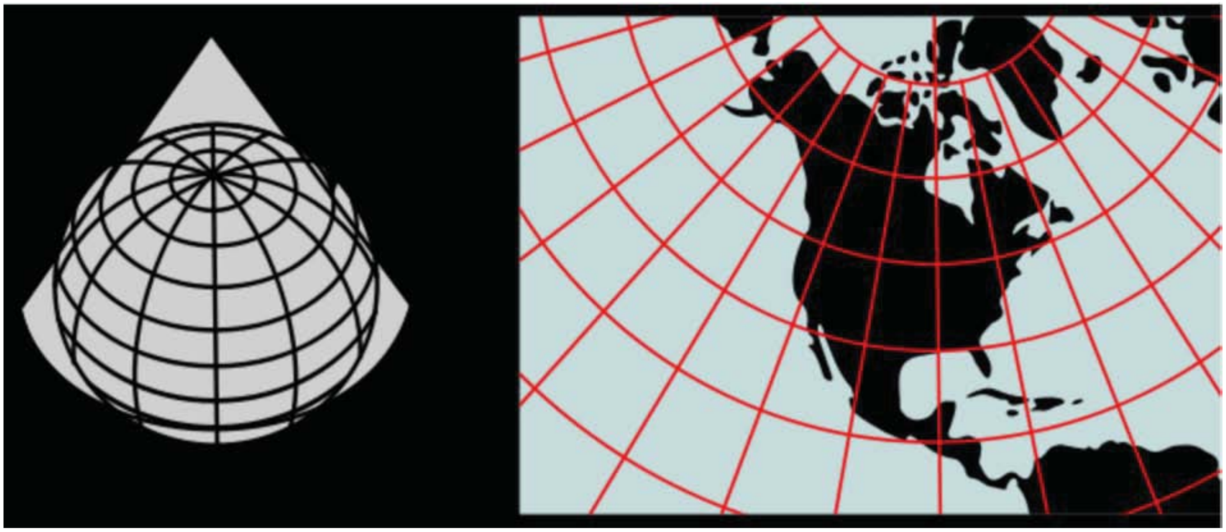

Figure 1 Lambert Conformal Conic Projection

Note. From "Image: Lambert Conformal Conic", *Wikimedia*. Retrieved November 27, 2008, from http://commons.wikimedia.org/wiki/Image:Lambert_conformal_conic.svg

The properties of the Lambert Conformal Conic Projection are:

- Meridians of longitude are slight curves or straight lines converging toward the nearer pole.
- Parallels of latitude are curves which are concave toward the nearer pole.
- The scale of distance is uniform throughout the entire chart.
- A straight line drawn between any two points on the chart represents an arc of a great circle.

VNCs and World Aeronautical Charts (WACs) are examples of Lambert Conformal Conic Projections.

The Transverse Mercator Projection. Applies the Mercator technique by rotating the cylinder 90 degrees so the point of tangency is a meridian of longitude rather than the equator. This projection is accurate in depicting scale, especially on charts covering a relatively small geographical area. The VFR Terminal Area (VTA) Charts are examples of Transverse Mercator Projections.

Using the globe and the sheet of flip chart paper, demonstrate wrapping a cylinder around the globe with its point of tangency at a meridian of longitude.

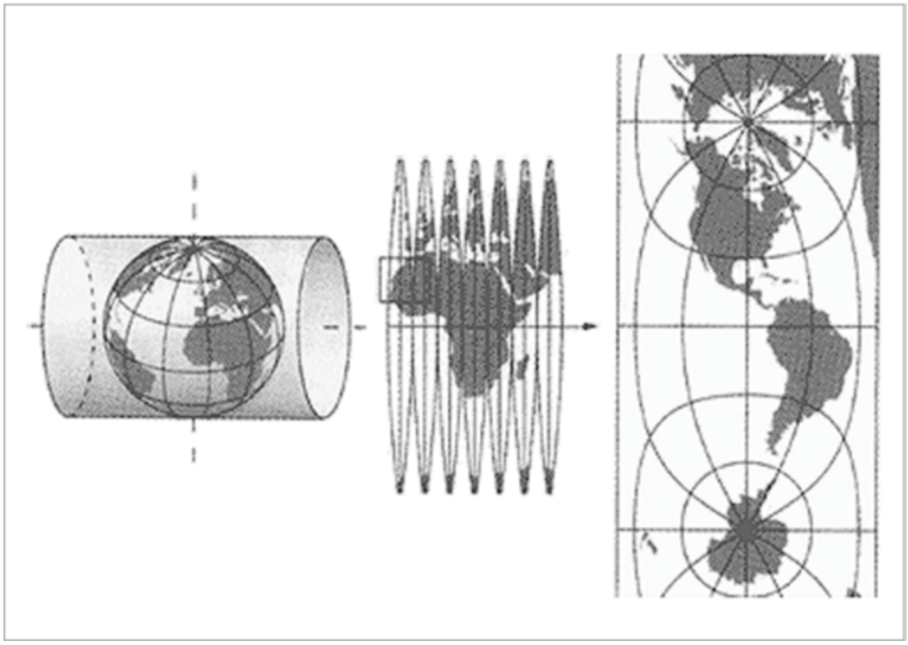

Figure 2 Transverse Mercator Projection

Note. From "Swiss Map Projections", 2008, *Federal Office of Topography Swisstopo*. Retrieved November 27, 2008, from http://www.swisstopo.admin.ch/internet/swisstopo/en/home/topics/survey/sys/refsys/projections.html

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CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What does a straight line drawn between any two points on a Lambert Conformal Conic Projection represent?

Q2. What are two examples of Lambert Conformal Conic Projections?

Q3. What is an example of a Transverse Mercator Projection?

ANTICIPATED ANSWERS:

A1. An arc of a great circle.

A2. VNCs and WACs.

A3. A VTA Chart is an example of a Transverse Mercator Projection.

Teaching Point 2	**Describe types of aeronautical charts.**
Time: 5 min	Method: Interactive Lecture

VFR NAVIGATION CHART (VNC)

Show the cadets a VNC.

VNCs are designed primarily for visual navigation at low altitudes and slow speeds. Each chart is identified by the name of a principal landmark on the chart (eg, Toronto, Winnipeg, Gander). The scale of the chart is 1 : 500 000 or about one inch to eight miles.

WORLD AERONAUTICAL CHART (WAC)

Show the cadets a WAC.

WACs are designed primarily for visual navigation at higher altitudes and greater speeds. Each chart depicts a sizeable portion of the country's geographical area—eighteen charts cover Canada. Each chart is identified by a letter and a number. For example, E17 covers the area from Marathon, Ont., west to Brandon, Man., and from the 48^{th} parallel north to Thompson, Man. The scale of the chart is 1 : 1 000 000 or about one inch to 16 miles.

VFR TERMINAL AREA (VTA) CHART

Show the cadets a VTA Chart.

VTA Charts are large scale charts (1 : 250 000) published for airports where there is a high volume of air traffic and where there is usually a mix of controlled airspace. Radio communication information and other information that is necessary for conducting flight through the area are given on the chart.

ENROUTE CHART

Show the cadets an Enroute Chart.

Enroute Charts provide information for radio navigation over designated airways systems. Enroute Charts do not portray any cities, towns, or topographical features. They depict all radio navigation aids, including airways, beacons, reporting points, and communication frequencies. Examples of Enroute Charts are Enroute Low Altitude Charts, Enroute High Altitude Charts, and Terminal Area Charts.

Canada Flight Supplement (CFS). A joint civil / military flight information publication and a supplement of the Aeronautical Information Publication (AIP). It contains information on Canadian and North Atlantic aerodromes. The CFS is designed to be used in conjunction with all Canadian charts and should be carried by every pilot departing on a flight. It is revised and reissued every 56 days.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. What is the scale of a VNC?

Q2. What are WACs primarily used for?

Q3. What are Enroute Charts used for?

ANTICIPATED ANSWERS:

A1. 1 : 500 000.

A2. Visual navigation at higher altitudes and greater speeds.

A3. Radio navigation.

Teaching Point 3 — **Explain, demonstrate and have the cadets practice locating landmarks on a VNC using latitude and longitude.**

Time: 15 min — Method: Demonstration and Performance

For this TP, it is recommended that the instruction take the following format:

1. Explain and demonstrate the skill while the cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice the skill.

Note: Assistant instructors may be used to monitor the cadets' performance.

USE LATITUDE AND LONGITUDE TO LOCATE LANDMARKS ON A VNC

The cadets were introduced to latitude and longitude in EO M437.01 (Define Air Navigation Terms). They were asked to find the coordinates of a major airport. In this TP, the cadets are given the coordinates and asked to find the landmarks. They should require minimal instruction as it is a review.

Give the cadets coordinates of several landmarks on a local VNC and have them identify the landmarks.

For example, 43°59'N, 80°17'W is a soaring site (Grand Valley).

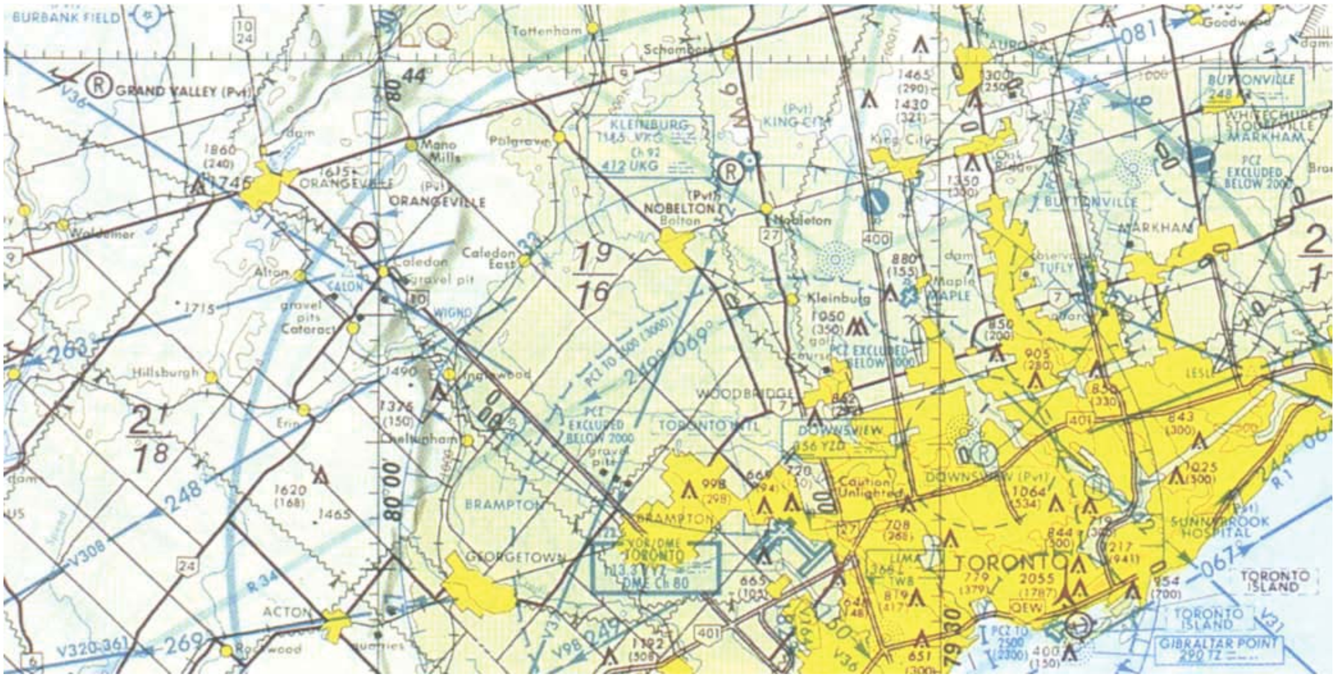

Figure 3 Example of a VNC

Note. From *Toronto VFR Navigation Chart*, by Geomatics Canada, 2001, Ottawa, ON: Geomatics Canada Department of Natural Resources. Copyright 2001 by NAV CANADA and Her Majesty the Queen in Right of Canada.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in locating landmarks on a VNC using latitude and longitude will serve as the confirmation of this TP.

Teaching Point 4	**Explain, demonstrate and have the cadets practice plotting tracks between landmarks on a VNC.**
Time: 5 min	Method: Demonstration and Performance

For this TP, it is recommended that the instruction take the following format:

1. Explain and demonstrate the skill while the cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice the skill.

Note: Assistant instructors may be used to monitor the cadets' performance.

PLOT A TRACK BETWEEN LANDMARKS ON A VNC

To plot a track between landmarks on a VNC:

1. Identify the landmarks.
2. Use a ruler to draw a straight line between the landmarks.

Give the cadets coordinates of a departure aerodrome and a destination aerodrome on a local VNC. Have them plot a track.

More advanced flight plan plotting (eg, 10-degree drift lines) will be taught during future aviation training.

CONFIRMATION OF TEACHING POINT 4

The cadets' participation in plotting tracks between landmarks on a VNC will serve as the confirmation of this TP.

Teaching Point 5 — **Explain, demonstrate and have the cadets practice measuring distances on a VNC.**

Time: 10 min — Method: Demonstration and Performance

For this TP, it is recommended that the instruction take the following format:

1. Explain and demonstrate the skill while the cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice the skill.

Note: Assistant instructors may be used to monitor the cadets' performance.

MEASURE DISTANCE ON A VNC

Measure distance on a VNC by:

- using a scale, or
- using an International Civil Aviation Organization (ICAO) ruler.

Using a Scale

The scale of the chart is the relationship between a unit of distance (eg, one inch) on the chart to the distance that the unit represents on the surface of the Earth.

There are two scales found on a VNC:

- **Representative fraction.** A ratio representing the distance on a map in relation to the surface of the Earth. The representative fraction of a VNC is 1 : 500 000 (one inch on the map represents 500 000 inches or eight miles).
- **Graduated scale line.** Three scale lines printed on the border of the chart representing kilometres, statute miles, and nautical miles. The distance between two locations on a VNC can be compared to one of these lines to give the represented distance in any of the three units of distance.

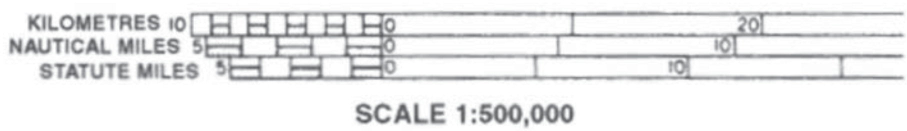

Figure 4 Graduated Scale Line

Note. From *From the Ground Up: Millennium Edition* (p. 123), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

To measure distance on a VNC using the representative fraction:

1. Use a ruler to measure the distance between two landmarks in inches.
2. Multiply the number of inches by eight to determine the distance in statute miles.

To measure distance on a VNC using the graduated scale:

1. Use a straightedge to measure the distance between two landmarks.
2. Line the straightedge up with the graduated scale, starting at the zero mark, to determine the distance in kilometres, nautical miles, or statute miles.

Have the cadets practice measuring distance using each technique.

Using an ICAO Ruler

ICAO ruler. A plastic straightedge graduated in both statute and nautical miles for use with 1 : 1 000 000 and 1 : 500 000 scale charts. On its reverse side, the ICAO ruler provides conversion factors, VHF reception distances, standard time conversions to Co-ordinated Universal Time (UTC), time equivalencies, flight plan sequences, and an aviation gasoline conversion table.

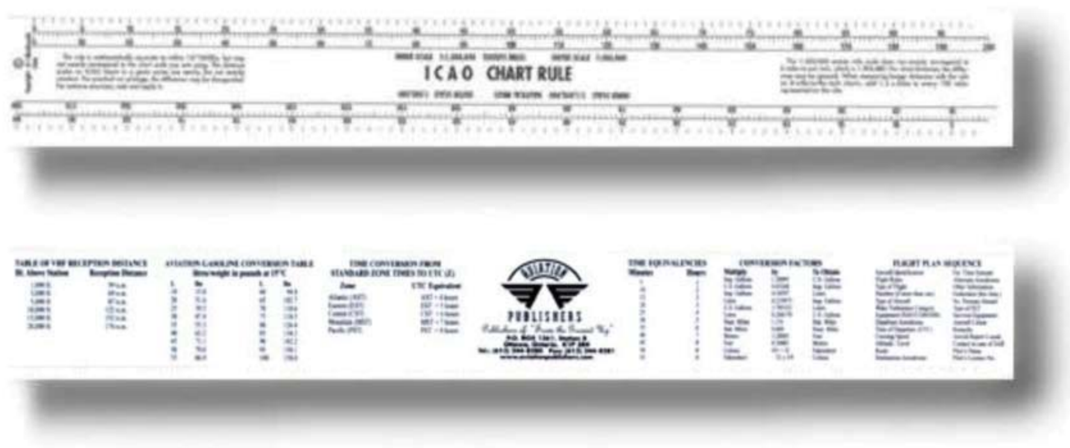

Figure 5 ICAO Ruler

Note. From "Other Publications", *Aviation Publishers*. Retrieved November 28, 2008, from http://www.aviationpublishers.com/otherpub/icao.html

To measure distance on a VNC using an ICAO ruler:

1. Align the edge of the ruler with the track. Ensure the zero mark is at one of the landmarks.
2. Read the desired scale (nautical miles or statute miles) where the ruler meets the other landmark.

Use the edge of the ICAO ruler meant for 1 : 500 000 scale charts.

Have the cadets practice measuring distance using this technique.

CONFIRMATION OF TEACHING POINT 5

The cadets' participation in measuring distances on a VNC will serve as the confirmation of this TP.

Teaching Point 6 | **Explain, demonstrate and have the cadets practice determining headings on a VNC.**

Time: 10 min | Method: Demonstration and Performance

For this TP, it is recommended that the instruction take the following format:

1. Explain and demonstrate the skill while the cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice the skill.

Note: Assistant instructors may be used to monitor the cadets' performance.

DETERMINE A HEADING ON A VNC

Douglas protractor. A tool used for determining headings and as a straightedge. It is transparent and has a compass rose graduated in 360 degrees marked around the outer edges.

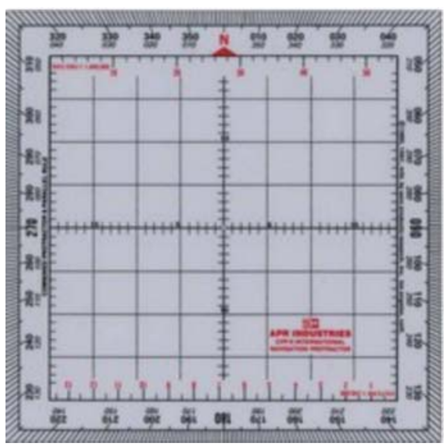

Figure 6 Douglas Protractor

Note. From "Douglas Protractor / Parallel Ruler", *VIP Pilot Centre*. Retrieved November 28, 2008, from http://www.canada-shops.com/Magasin/vippilotcenter/c46907p95758.2.html

To determine a heading on a VNC using a Douglas protractor:

1. Place the protractor on the chart with the hole in the centre lying on the track at a point where the north-south line on the protractor lies along the meridian of longitude. If this is not convenient, one of the vertical lines can be lined up parallel with the nearest meridian.
2. Read the heading where the track cuts the edge of the protractor.

Have the cadets determine the headings of the tracks previously plotted. Have them plot more tracks and determine the headings as time permits.

CONFIRMATION OF TEACHING POINT 6

The cadets' participation in determining headings on a VNC will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

The cadets' performance of locating landmarks, plotting tracks, measuring distances, and determining headings on a VNC will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Flight planning and navigating at low altitudes and slow speeds relies on being able to use a VNC. Many of the skills used with this chart are transferable to other types of maps both in the air and on the ground.

INSTRUCTOR NOTES / REMARKS

Assistant instructors may be required for this lesson.

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.