**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.



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**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 $V_{NO}$.



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**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.



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"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.

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**ACTIVITY**

Time: 10 min

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**OBJECTIVE**

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



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**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.



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## 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



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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.



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**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.



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**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.



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## 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.



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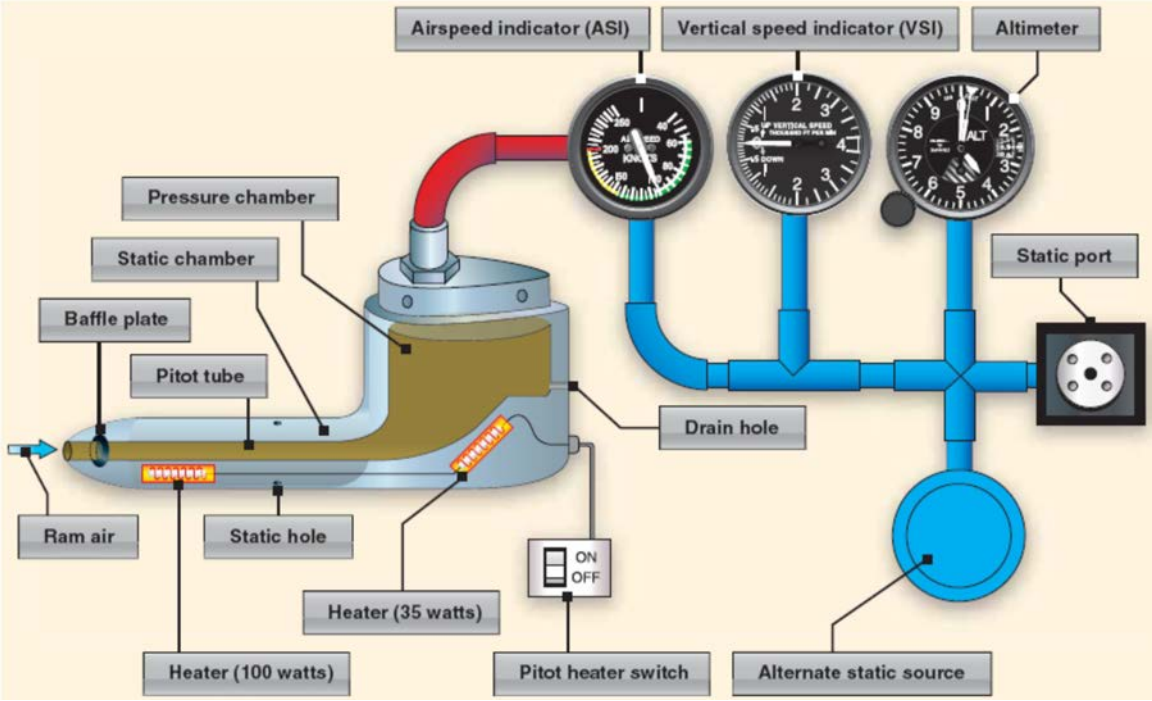


*Note. From "Pilot's Handbook of Aeronautical Knowledge", Federal Aviation Administration. Retrieved November 19, 2008, from http://www.faa.gov/library/manuals/aviation/media/FAA-H-8083-25A.pdf*

Figure A-1 Pitot Static System




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

Figure A-2 Airspeed Indicator



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*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



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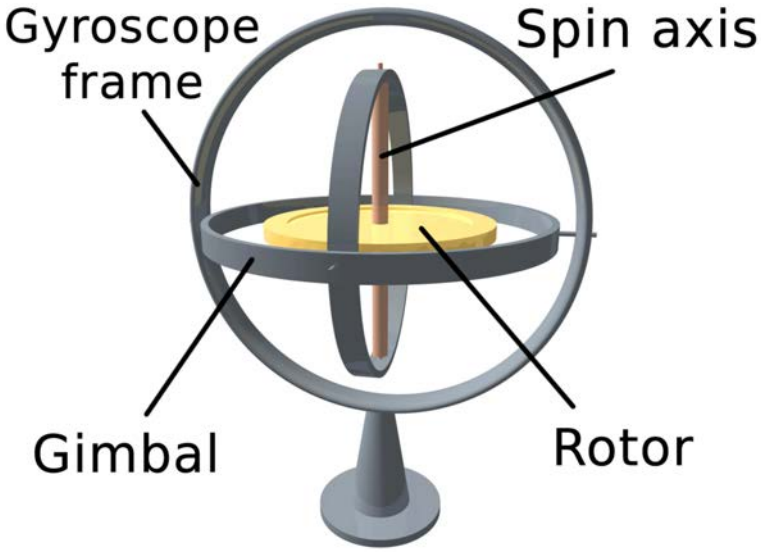
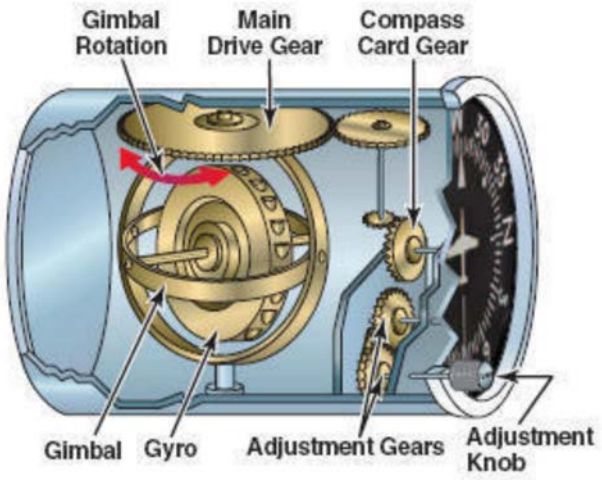



*Note. From "3D Gyroscope", Wikimedia. Retrieved November 18, 2008, from http://upload.wikimedia.org/wikipedia/commons/e/e2/3D_Gyroscope.png*

Figure A-5 Gyroscope




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

Figure A-6 Heading Indicator



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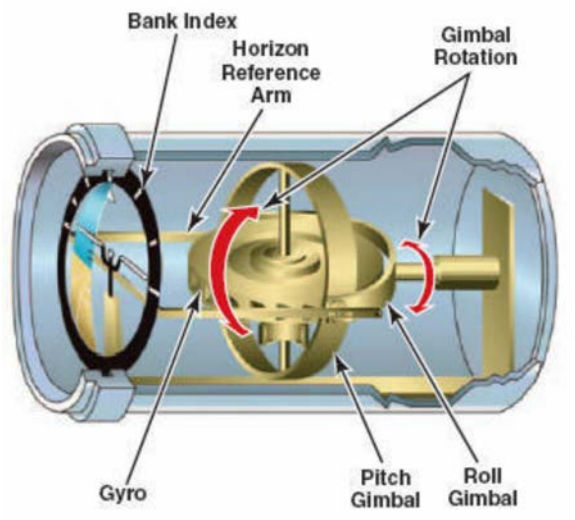


*Note. From "The Journal for the Proficient Pilot", Over the Airwaves. Retrieved November 18, 2008, from http://overtheairwaves.com/vol3-45.jpg*

Figure A-7 Attitude 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-8 Turn and Bank Indicator



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

Figure A-9 Turn Co-ordinator




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

Figure A-10 AOA Indicator




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

Figure A-11 Mach Indicator



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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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