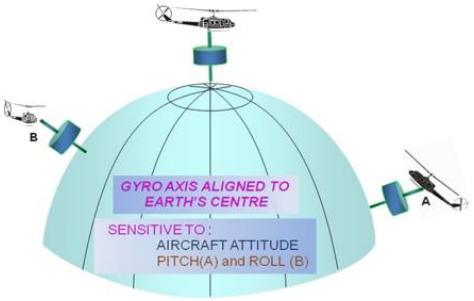
ATTITUE INDICATOR

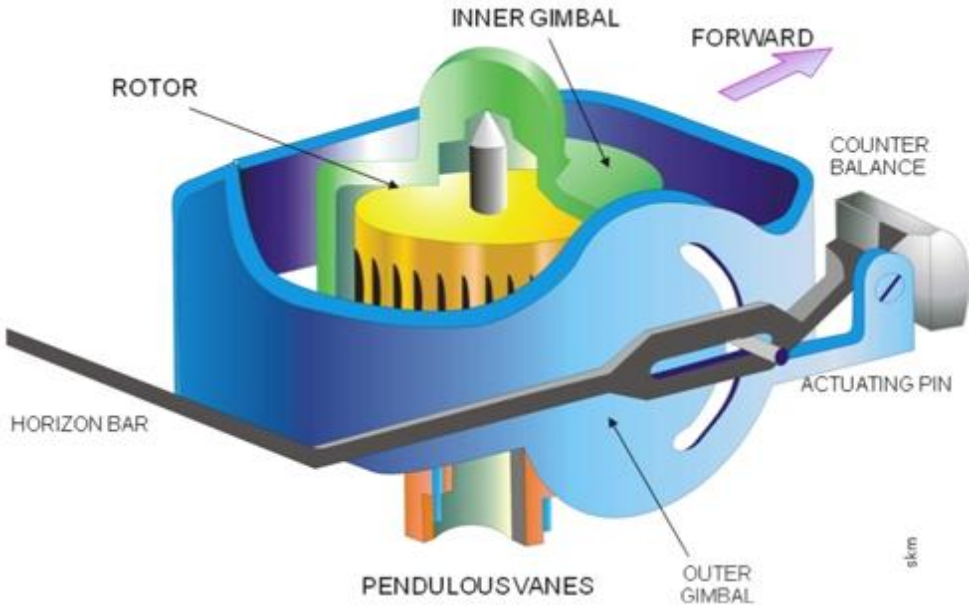
Attitude Indicator, also known as *Artificial Horizon* provides a pilot with direct and continuous indication of pitch and roll information of his helicopter. In poor visibility and instrument flying conditions, it provides a horizon reference and replaces the natural horizon.

Principle of Operation. Gyro axis of the instrument is kept aligned to local vertical by utilizing Earth's gravity and therefore, the rotor always spins in the horizontal plane, as shown in the figure on the left. The gyro spin axis is kept vertical by Earth's gravity; therefore the gyro is called an *Earth Gyro*. Any pitching movement about the lateral axis of the helicopter is indicated on the instrument by relative position of miniature aircraft symbol with respect to a horizon bar and sky plate - representing a horizon artificially. A picture of the instrument, *not in operating mode*, is shown on the right. Whenever the helicopter banks, the miniature symbol appears to bank in relation to the horizon on the instrument. Thus, the attitude information of the helicopter with reference to real horizon is available throughout. A pointer, moving behind the bank angle scale which is marked on the glass face of the instrument, indicates the angle of bank.

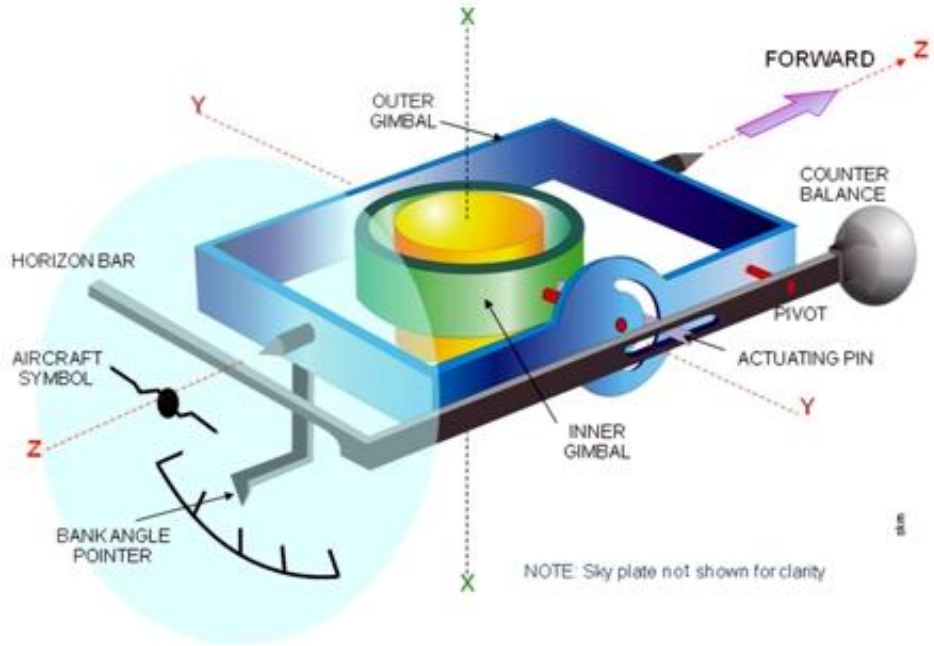


AIR DRIVEN ATTITUDE INDICATOR

Construction. A vertical gyro rotating at about 15,000 rpm is contained within an inner gimbal. As shown in the figure here, the inner gimbal itself forms casing of gyro for



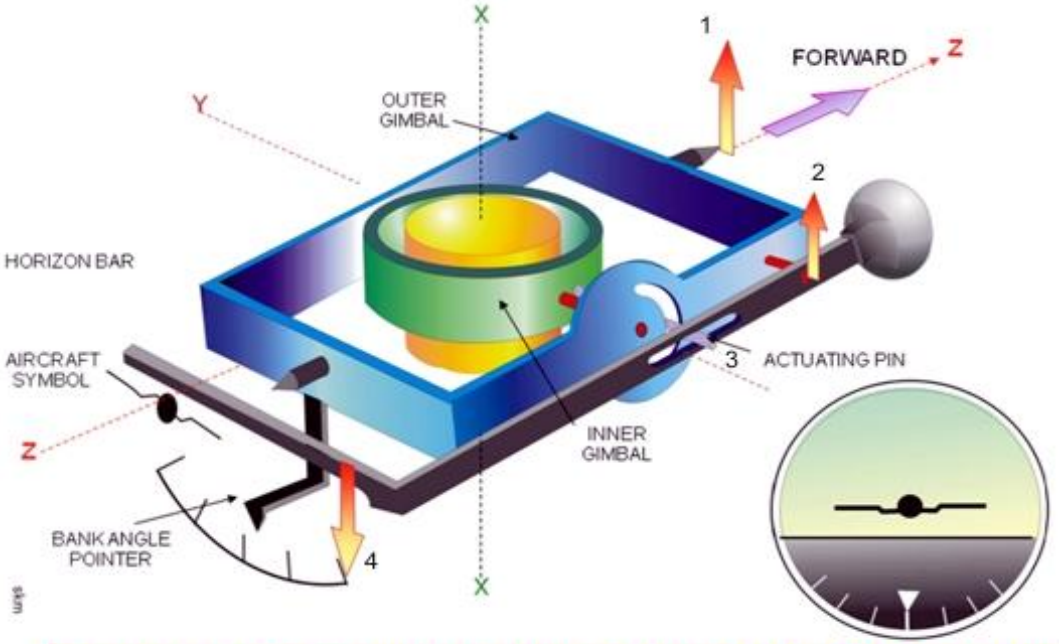
the air driven type of attitude indicators. The inner gimbal is pivoted to an outer gimbal along an axis that is parallel to lateral axis of helicopter as shown below. The outer gimbal



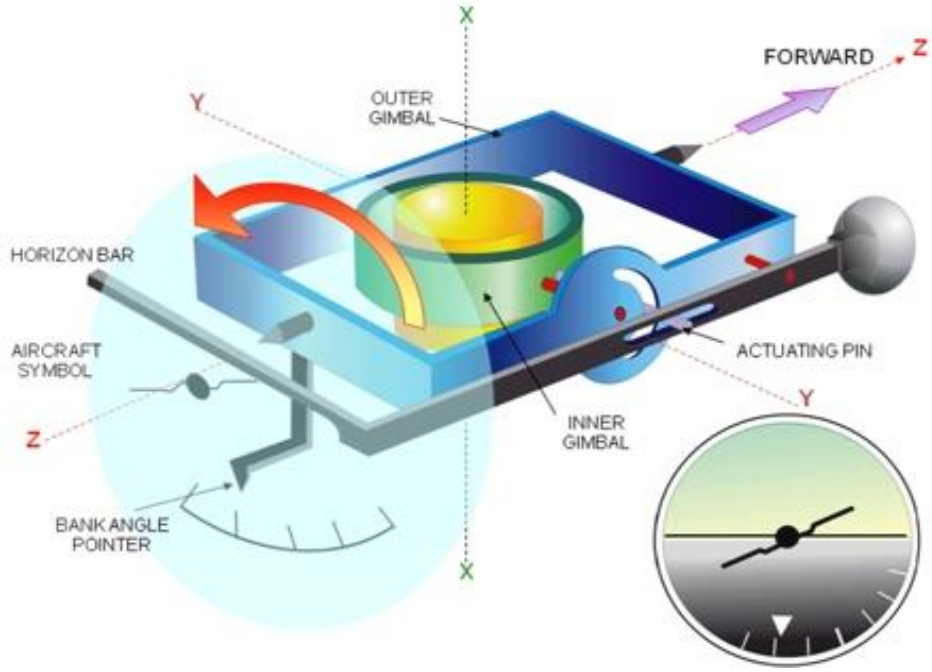
is in turn pivoted to body of the instrument along an axis which is parallel to helicopter's longitudinal axis. Since the instrument body is attached to the airframe, pitch changes in helicopter's attitude would result in the outer gimbal pitching up or down with respect to the horizon. With helicopter rolling to any side, left or right, the gyro system maintains orientation and allows free movement about the longitudinal axis of the helicopter.

The face of the instrument is seen as a horizon because of a sky plate which is divided horizontally, pale blue above and black below, to represent the sky and the earth respectively. The sky plate is attached to the outer gimbal. A horizontal bar, called horizon bar, extending across the sky plate is also attached to the outer gimbal by a pivoted spindle bar. The horizon bar moves up or down as the spindle bar is pushed through a slot by an actuating pin attached to the inner gimbal. A counter balancing weight is provided to compensate for long length and weight of the bars. A miniature aircraft is mounted in the centre of the instrument dial, generally with a provision for altering the vertical position of miniature aircraft with help of a pitch attitude adjuster knob. This combined with caging device knob is seen in picture of the attitude indicator shown earlier on previous page.

Operation. In straight and level flight, the gyro spin axis remains at 90° to both the longitudinal and lateral axes of the helicopter, while the miniature aircraft symbol and horizon bar appear in the mid position. Now if the helicopter's nose is pitched up, as shown in the figure on the next page, the outer gimbal will also be pitched up with it (1). Front of the outer gimbal will be raised up relative to vertical seeking gyro spin axis. As spindle bar is pivoted on the outer gimbal (2), and the actuating pin is attached to inner gimbal keeping its rigidity, it would exert a downward pressure on the spindle (3) and horizon bar (4). Their downward movement relative to the aircraft symbol would indicate a climb. The reverse would happen in case of descent.

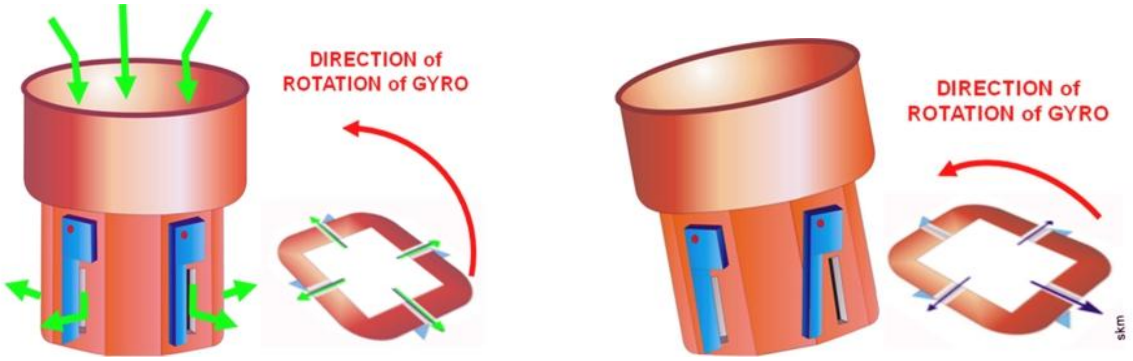


Bank indication is given by the angle of the horizon bar relative to the aircraft symbol. The gyro with its property of rigidity, maintains the outer gimbal and attached horizon bar horizontal throughout. Actually the aircraft symbol, on the glass face of the instrument (or on a fixed post) rolls along with the helicopter while the indicated horizon is



maintained horizontal by the gyro. Bank angle in degrees is indicated by a pointer attached to the outer gimbal moving behind a scale painted on the glass face. It should be noted that, it is the rotation of the glass face against vertical pointer that indicates the bank angle.

Erection Mechanism. Air driven attitude indicators have a *pendulous unit* attached at the bottom of the inner gimbal to maintain the spin axis vertical. Action of gravity on four hinged vanes covers only half of the exhaust ports while the unit is vertical. The



replacement air (in suction type gyro) sucked in through a fine fitter after impinging on rotor buckets rushes through the pendulous unit and the four exhaust ports into the instrument body. The reaction forces from each of the exhaust ports remain in balance as shown in figure above on the left, while the gyro rotation axis is vertical. Whenever, the spin axis moves off the vertical, as in figure on the right, the opposite vanes of each pair (force and aft for roll correction and lateral for pitch correction) are displaced in such a manner, that one vane covers more of its exhaust port than the opposite one. The reaction forces, now out of balance, produce a torque such that the gyro axis precesses back to the vertical.

Errors of Air-driven Attitude Indicator

Main errors of air-driven attitude indicator are caused due to use of pendulous unit and are enumerated here.

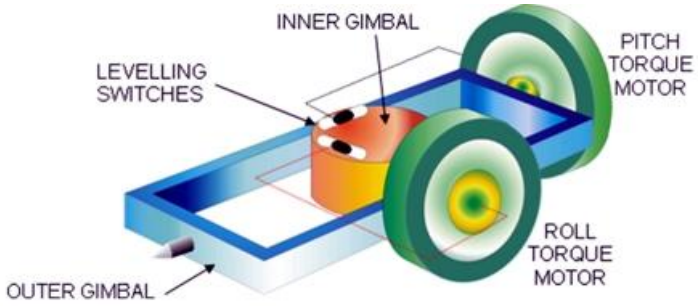
Acceleration Error. Indication of a *climbing turn to the right* during straight and level acceleration is caused by the pendulous nature of the levelling mechanism. During acceleration the pitch correcting vanes (on the left and right side) are displaced towards the pilot by their inertia. The resultant precession of the pendulous unit towards the pilot is indicated as false climb. Secondly, inertia of the pendulous unit acting at its low C of G, at the same time, processes the unit to the left. This tilt of the unit is reflected as an apparent turn to the right. As the precession depends on duration and rate of acceleration, no correction can be applied to the instrument. Opposite effect takes place for any deceleration in level flight where an apparent descending turn to the left is indicated.

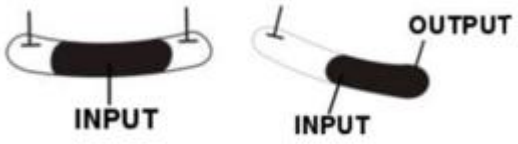
Turning Error. The second main error is caused by the centrifugal force acting on the pendulous unit and the vanes. The result is to cause a combined bank and pitch error. Centrifugal force acting at 90° to the fore and aft axis, acts on the fore and aft vanes and produces unbalanced reaction force acting parallel to fore and aft axis. Based on direction of the turn and the spin direction of the gyro, a left or right bank error is caused. The centrifugal force also acts at low C of G of the pendulous unit and causes it to either pitch up or down depending again on the direction of turn and gyro rotation. The error is compensated in most instruments for Rate One Turn and at a particular speed. The residual error, at other speeds and rates of turn, is much less than in an uncorrected instrument. In general, the turning errors are less in magnitude than acceleration error.

ELECTRICALLY DRIVEN ATTITUDE INDICATOR

Essentially the principle of operation of electrically driven attitude indicator is same as that that of air driven attitude indicator. The vertical gyro unit in this case is basically an electric motor rotating at around 22,000 rpm, therefore providing a higher stability to the system.

Erection Mechanism. The gyro axis is kept vertical using two torque motors mounted on the outer gimbal and controlled by levelling switches. The torque motors are AC induction motors whose stators are mounted on the outer gimbal and are aligned with lateral and longitudinal axes of helicopter, as shown in the figure below. Energizing the stator tends to rotate the rotor surrounding it which is opposed by the rigidity of the gyro. Resulting torque reaction acts about the axis of the motor and corrects the error of the outer gimbal in pitch or roll. Two levelling switches are in the form of small curved tube, partially filled with mercury, provided with an input and two output contacts, as shown on the right in the figure below. These are mounted on the inner gimbal of the gyro, along the longitudinal and lateral axes of the helicopter. Whilst the inner gimbal remains horizontal, no current flows because mercury is centralised and no output contact is made. With tilting of the outer gimbal to any side associated switch is also tilted and mercury flows to one end of the tube making a contact with output. Based on direction of the tilt, related torque motor now applies a torque in appropriate direction that the error in tilt (pitch or roll) is corrected. Once inner gimbal is restored to horizontal position, the levelling switch will be in neutral (with mercury centralized) position and electrical supply to the torque motor will be cut off. Some electrically driven gyros may use a different system - slotted disc and ball system or ball cluster system, both utilizing Earth's gravity.





Acceleration and Turning Errors. Like the pendulous system of air-driven attitude indicator, the levelling switches are also susceptible to acceleration. Application of any acceleration would force the mercury in the levelling switches to move to one end and make the electrical contact to one or both torque motors. Torque applied by motors would lead to false indications similar to those described earlier for air-driven attitude indicator. The fore and aft orientated levelling switch would sense the speed accelerations and drive the pitch motor to indicate a false pitch movement. Similarly, the lateral levelling switch affected by centrifugal force during turns would result in indication of a false climb or descent due to rotation of roll torque motor. A cut-out system to detect any horizontal acceleration and isolate the electrical circuits to the torque motors, is incorporated to prevent indication of false bank or pitch.

WARNING and LIMITATIONS

Failure of pressure system (compressor or suction) in air driven attitude indicator may be displayed by a warning flag appearing on the face of the instrument. Electrically driven instrument may display a typical 'Off' flag when power is not supplied. Air driven instruments take over five minutes to erect after start-up. Those equipped with a caging device the duration for initial set-up may be reduced by locking the gimbals as in direction indicator. In some electrically driven attitude indicators provided with fast erection system this time may be reduced to one minute.

Air driven attitude indicators, generally have freedom to roll ±90° and to pitch ±60° (climb or dive). Electrically driven ones have higher limits; complete freedom to roll and ± 85° for pitching. All types have natural complete freedom in yaw that is about axis of rotation of gyro. A caging device controlled by a knob operated by pilot on the instrument may be provided for locking the instrument before carrying out any harsh manoeuvres.

PILOT'S SERVICABILITY CHECKS

- Check no failure flag showing/ or suction gauge has desired vacuum pressure, as applicable.
- Check for any physical damage to the glass face.
- During pre-flight check the horizon bar in level position and is positioned in correct pitch indication within reasonable time of power switched on.
- Check while taxiing, horizon indications are correctly maintained.
- In-flight check that the indications are correct in their sense of bank and pitch in relation to visual observation of the natural horizon.

SUMMARY

ATTITUDE INDICATOR provides direct and continuous indication of pitch and roll information.

Principle. A vertical axis *Earth Gyro* provides reference datum, aligned to Earth's centre. Any pitch or roll about their respective axes is indicated on the instrument by relative position of miniature aircraft symbol in relation to a horizon bar and sky plate - representing an artificial horizon.

CONSTRUCTION

Air-Driven Gyro. 15,000 rpm. Inner gimbal forms gyro casing and pivoted along lateral axis to outer gimbal, which in turn is pivoted to instrument body along fore and aft axis of the helicopter. Pitch changes result in outer gimbal moving up or down. Instrument freely rolls about longitudinal axis. Pendulous unit with four exhaust ports and vanes maintains vertical.

Operation. Nose up movement results in horizon bar and sky plate attached to outer gimbal moving down in relation to aircraft symbol; showing pitch up. Bank angle is indicated by the pointer attached to outer gimbal remaining vertical and instrument scale painted on the glass face moving with helicopter rolling.

Electrically-Driven Gyro. Basically electrical motor spinning at higher speed of 22,000 rpm, operating similar to air driven type. Spin axis vertical is maintained by two electrical levelling switches controlling respective torque motors. Gyro tilt causes levelling switch(es) to connect power to torque motor(s) such that the resultant precession corrects the misalignment.

ERRORS

Acceleration. Straight and level acceleration causes *climbing turn to the right*. Pitch correcting vanes (on the left and right side) are displaced towards the pilot by their inertia. The resultant precession of the pendulous unit towards the pilot is indicated as false climb. Secondly, the pendulous unit with low C of G, processes the unit to the left showing an apparent turn to the right. No correction can be applied to the instrument. Similar effect on levelling switches caused torque motors to precess the gyro.

Turning. Centrifugal force acting on the pendulous unit and the fore and aft vanes causes a combined bank and pitch error. It produces an unbalanced reaction force acting parallel to fore and aft axis. Based on direction of the turn and the spin direction of the gyro, a left or right bank error is caused. It also acts at low C of G of the pendulous unit and causes it to either pitch up or down depending again on the direction of turn and gyro rotation. The error is compensated in most instruments for Rate One Turn and at a particular speed. Levelling switches in electrically driven gyro cause this error. A cut-out system isolates the electrical circuits to the torque motors, to prevent indication of false bank or pitch.

Limitations. Air driven: roll ±90° and pitch ±60° (climb or dive).
Electrically driven: roll complete freedom and pitch ± 85°.

SAMPLE QUESTIONS: ATTITUDE INDICATOR

1. Purpose of an attitude indicator is to provide;
   (a) an artificial horizon to exercise control during climb and turns.
   (b) a reference in absence of natural horizon so that pilot can fly at same level.
   (c) direct and continuous indication of pitch and roll information.
   (d) information on angle of attack and bank angle.

2. An attitude indicator user a vertical axis gyro which is known as;
   (a) earth gyro.
   (b) vertical gyro.
   (c) free gyro.
   (d) rate gyro.

3. Attitude indicators, air driven or electrical, use earth's gravity to maintain the;
   (a) spin axis aligned to vertical axis of the helicopter
   (b) spin axis aligned to fore and aft axis of the helicopter.
   (c) plane of the rotor in the local horizontal plane.
   (d) spin axis horizontal to show artificial horizon on the instrument

4. Attitude indicator uses an …… driven gyro with approximate spin rate of ……..rpm and spin axis aligned to the ……..
   (a) electrically, 15,000, vertical.
   (b) air driven, 22,000, horizontal.
   (c) electrically, 22,000, horizontal.
   (d) air driven, 15,000, vertical.

5. Outer gimbal of an attitude indicator is pivoted to instrument body along helicopter's;
   (a) lateral axis.
   (b) Vertical axis.
   (c) fore and aft axis.
   (d) local vertical with respect to earth.

6. Gyros used in attitude indicator are;
   (a) either driven by air pressure or by section.
   (b) either air driven or electrically driven.
   (c) always electrically driven to achieve higher rigidity.
   (d) always pneumatic type as pendulous suspension is used for vertical alignment.

7. When helicopter climbs, nose up attitude is indicated by;
   (a) horizon bar moving up from the mid-position.
   (b) sky plate moving up with outer gimbal.
   (c) horizon bar moving down from the mid-position.
   (d) sky plate moving down with the inner gimbal.

8. Bank angle on an attitude indicator is shown by a pointer attached to;
   (a) inner gimbal and moving against a scale on sky plate.
   (b) outer gimbal and moving against a scale on glass face.
   (c) outer gimbal and remaining vertical against scale on sky plate.
   (d) outer gimbal and remaining vertical against a scale marked on glass face.

9. The errors of an attitude indicator are;
   1. Acceleration
   2. RPM variation
   3. Latitude
   4. Turning
   5. Lag

   (a) 1,2 and 3.
   (b) 1 and 4.
   (c) 1,2 and 4.
   (d) 1,3 and 5.

10. Acceleration in level flight on attitude indicator shows a false;
   (a) descending turn to right.
   (b) descending turn to left.
   (c) climbing turn to left.
   (d) climbing turn to right.

11. On reduction of speed in level flight, attitude indicator will indicate a false turn to;
   (a) left and pitch down.
   (b) right and pitch up.
   (c) right and pitch down.
   (d) left and pitch up.

12. While turning false indication of pitch and bank is caused by the centrifugal force acting on;
   (a) pendulous unit and vanes.
   (b) inner gimbal as a torque.
   (c) outer gimbal as a torque.
   (d) actuating pin and counter balance weight.

13. Erection mechanism used in electrically driven attitude indicator may be;
   (a) a pendulous unit with pendulous vanes.
   (b) mercury levelling switches with pitch and roll motors.
   (c) a ball erector unit.
   (d) none of the above.

14. In an electrically driven attitude indicator there are two levelling switches. Pitch levelling switch is mounted on;
   (a) outer gimbal and aligned with fore and aft axis.
   (b) inner gimbal and aligned with fore and aft axis.
   (c) outer gimbal and aligned with lateral axis.
   (d) inner gimbal and aligned with lateral axis.

15. In most attitude indicators the turning errors;
    (a) are left uncorrected.
    (b) are calibrated and correction details are provided in pilot's manual.
    (c) are corrected for rate one turn at a particular speed.
    (d) being less than acceleration errors are not corrected.

16. Acceleration errors in most attitude indicators are;
    (a) not corrected as amount of error depends upon rate and duration of acceleration.
    (b) corrected for the range around normal cruising TAS.
    (c) not corrected as these are far less than the turning errors.
    (d) corrected by providing mercury filled levelling switches.

17. A warning flag to indicate failure of attitude indicator will normally be provided;
    (a) only in electrically driven gyro system
    (b) in both, air driven and electrically driven systems
    (c) only in air driven suction type of system
    (d) in any air driven gyro system

18. To shorten the start up erection process in attitude indicator;
    (a) fast erection system for start up may be provided.
    (b) a caging device may be provided.
    (c) both (a) and (b) may there.
    (d) any one of (a) or (b) may there.

19. If inner gimbal topples rearwards, the …….. levelling switch aligned with the instrument's……axis will not be affected and …… levelling switch will be tilted.
    (a) roll, pitch, pitch
    (b) roll, roll, pitch
    (c) pitch, pitch, roll
    (d) pitch, pitch, roll

20. While turning right, bank in attitude indicator is displayed due to the pointer attached to outer gimbal;
    (a) moving over a scale printed on the sky-plate.
    (b) remaining vertical and glass face with the scale painted on it rotating to the right.
    (c) moving in opposite direction against gyro stabilized sky-plate.
    (d) moving in opposite direction behind scale painted on the glass face.

ANSWERS: ATTITUDE INDICATOR

Question	Option
1	c
2	a
3	c
4	d
5	c
6	b
7	c
8	d
9	b
10	d
11	a
12	a
13	b
14	b
15	c
16	a
17	b
18	d
19	a
20	b